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Waterways Experiment Station

An Evaluation of Solidification/Stabilization for Treatment of Contaminated Soils From the Umatilla Army Depot Activity

by Michael G. Channell

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Prepared for U.S. Army Engineer District, Seattle

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Final report

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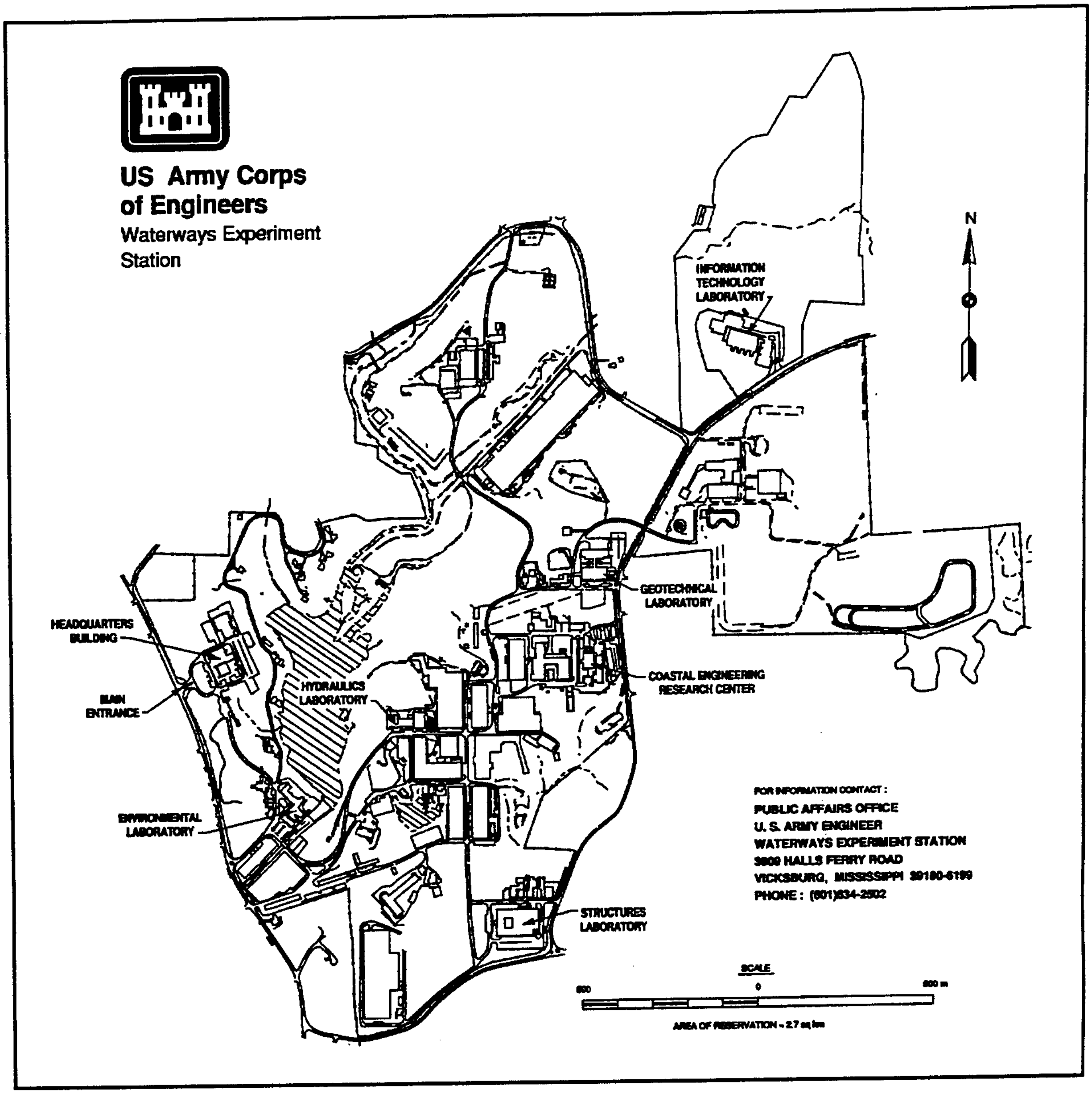

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Preface

The report herein was prepared for the U.S. Army Engineer District, Seattle, by the U.S. Army Engineer Waterways Experiment Station (WES). The work was performed during the period 20 June 1994 through 15 August 1994 by Mr. Michael G. Channell of the Environmental Restoration Branch (ERB), Environmental Engineering Division (EED), Environmental Laboratory (EL), WES. Chemical analyses were performed by the Environmental Chemistry Branch, EED.

The work was conducted under the direct supervision of Mr. Daniel E. Averett, Chief, ERB, and the general supervision of Mr. Norman R. Francingues, Chief, EED, and Dr. John W. Keeley, Director, EL. Project officers for the U.S. Army Engineer District, Seattle, were Messrs. Jim McBane, Mike Nelson, and John Wakeman.

At the time of publication of this report, Dr. Robert W. Whalin was Director of WES. COL Bruce K. Howard, EN, was Commander.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic feet	0.02831685	cubic meters
degrees (angle)	0.01745329	radians
Fahrenheit degrees	5/9	Celsius degrees or kelvins[1]
feet	0.3048	meters
foot-pounds (force)	1.355818	meter-newtons or joules
gallons (U.S. liquid)	3.785412	liters
inches	2.54	centimeters
miles (U.S. statute)	1.609347	kilometers
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.4535924	kilograms
quarts (U.S. liquid)	0.9463529	liters
square inches	6.4516	square centimeters

[1] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain kelvin (K) readings, use the following formula: $K = (5/9)(F - 32) + 273.15$.

1 Introduction

Background

The U.S. Army Umatilla Depot Activity (UMDA) is a 19,700-acre[1] military reservation that was established as an ordnance depot in 1941. The installation is situated within Morrow and Umatilla counties of northeastern Oregon, about 3 miles south of the Columbia River. The town of Hermiston, OR, is located about 4 miles east of UMDA, via Interstate 84. A regional map locating the UMDA is provided in Figure 1. The primary mission of the UMDA is to store, preserve, and perform minor maintenance on conventional and chemical munitions. The UMDA also stores strategic materials for the Defense Logistics Agency and reserve equipment withdrawn from normal service.

Eight operable units (OUs) have been identified at the UMDA that have the possibility of being contaminated. These OUs are as follows:

a. Inactive landfills.

b. Active landfills.

c. Groundwater contamination from the explosives washout lagoon.

d. Miscellaneous sites (operable units-5).

e. Ammunition demolition activity area (ADA).

f. Explosives washout plant (Building 489).

g. Washout lagoon soils.

h. Deactivation furnace and surrounding soils.

From the 1940s until present, UMDA operated periodically at the 32 miscellaneous sites identified as Operable Units-5 (OU-5). The 32 sites of OU-5

[1] A table of factors for converting non-SI units of measurement to SI units is presented on page ix.

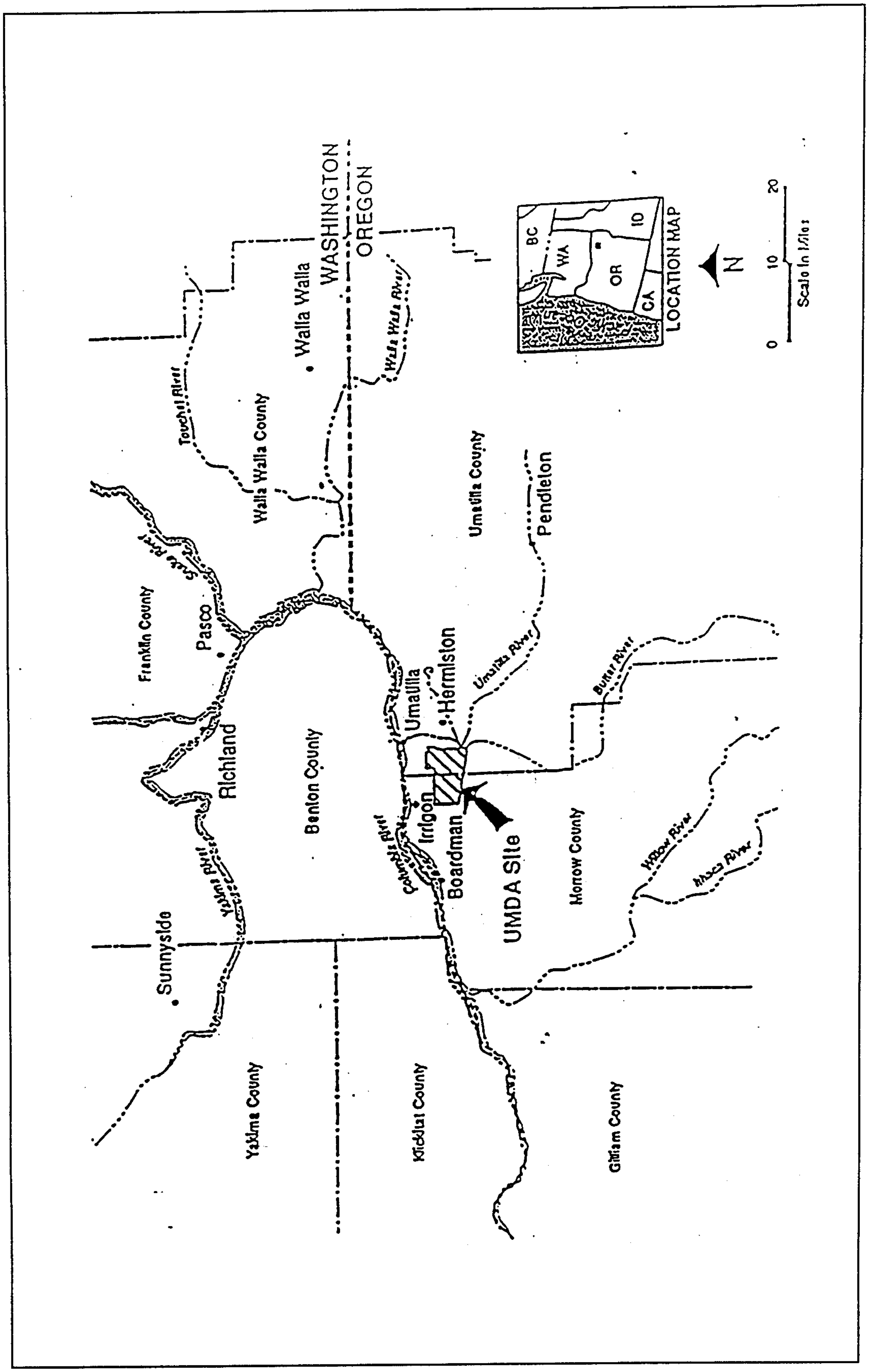

Figure 1. Location of UMDA

are located throughout UMDA as shown in Figure 2. Many of the sites are clustered in the southwestern and southern portion of the UMDA. The southwestern cluster of sites centers on warehousing, railroad unloading, and stockpiling activities. The southern portion of UMDA includes the administrative areas as well as support activities such as sewage treatment and storm-water discharges that are responsible for a cluster of OU-5 sites. The remaining OU5 sites are spread throughout UMDA and relate to a variety of mission activities and support facilities for mission activities. Typical activities conducted at the miscellaneous sites have involved a range of chemical compounds and metals, including explosives contained in ordnance being burned, detonated, or disposed and metals contained in ordnance and munitions casings being burned, detonated, or disposed of onsite.

The ADA (OU-4) is located in the western portion of the UMDA. Twenty sites have been identified as areas where historical or current activities have included burning, detonation, and disposal of ordnance and solid waste at the ADA. The location of these sites is indicated in Figure 3. Activities involved a range of chemical compounds and metals, including explosives and metals contained in ordnance being burned, detonated, or disposed of by dumping or burial.

Five sites were chosen for evaluation using current solidification/ stabilization technology. The five sites were identified as Sites 22 and 36 from the miscellaneous sites OU-5 and Sites 15, 19, and 31 from the ADA. Site 22 is the Defense Re-utilization Marketing Office (DRMO). The DRMO Area is located in the southwest portion of the UMDA administration area. This site is used to store scrap and salvage materials, including metals, wooden crates, waste oils, and old transformers, as well as scrap metal, empty shells and cartridges, vehicles, and furniture. These materials are stored in a warehouse building or outside on a paved area or bare ground while awaiting sale or offsite disposal. Site 36 is Building 493, the Paint Sludge Discharge Area. Paint spray booths used in Building 493 near the Explosive Washout Plant reportedly discharged paint sludge, solvents, and possibly other wastes into the coulee northwest of the building via an underground drainage system. Abundant paint stains were observed on soil near the two pipe discharge locations located along the coulee.

Site 15 is the TNT Sludge Burial and Burn Area. This area is located in the north-central portion of the ADA. Previous investigations at this site concluded that TNT-containing sludges from the Explosives Washout Plant (Building 489) may have been dumped and burned at Site 15. Site 19 is the Open Burning Trenches/Pads. The open burning trenches/pads are located in the north-central portion of the ADA. The trenches were reportedly used to burn a variety of debris and waste including ordnance waste and explosive sludges from the Explosives Washout Plant. Site 31 is the Pesticide Pits. The pesticide pits are located in the south-central portion of the ADA. These pits were used to burn or dispose of pesticide solutions.

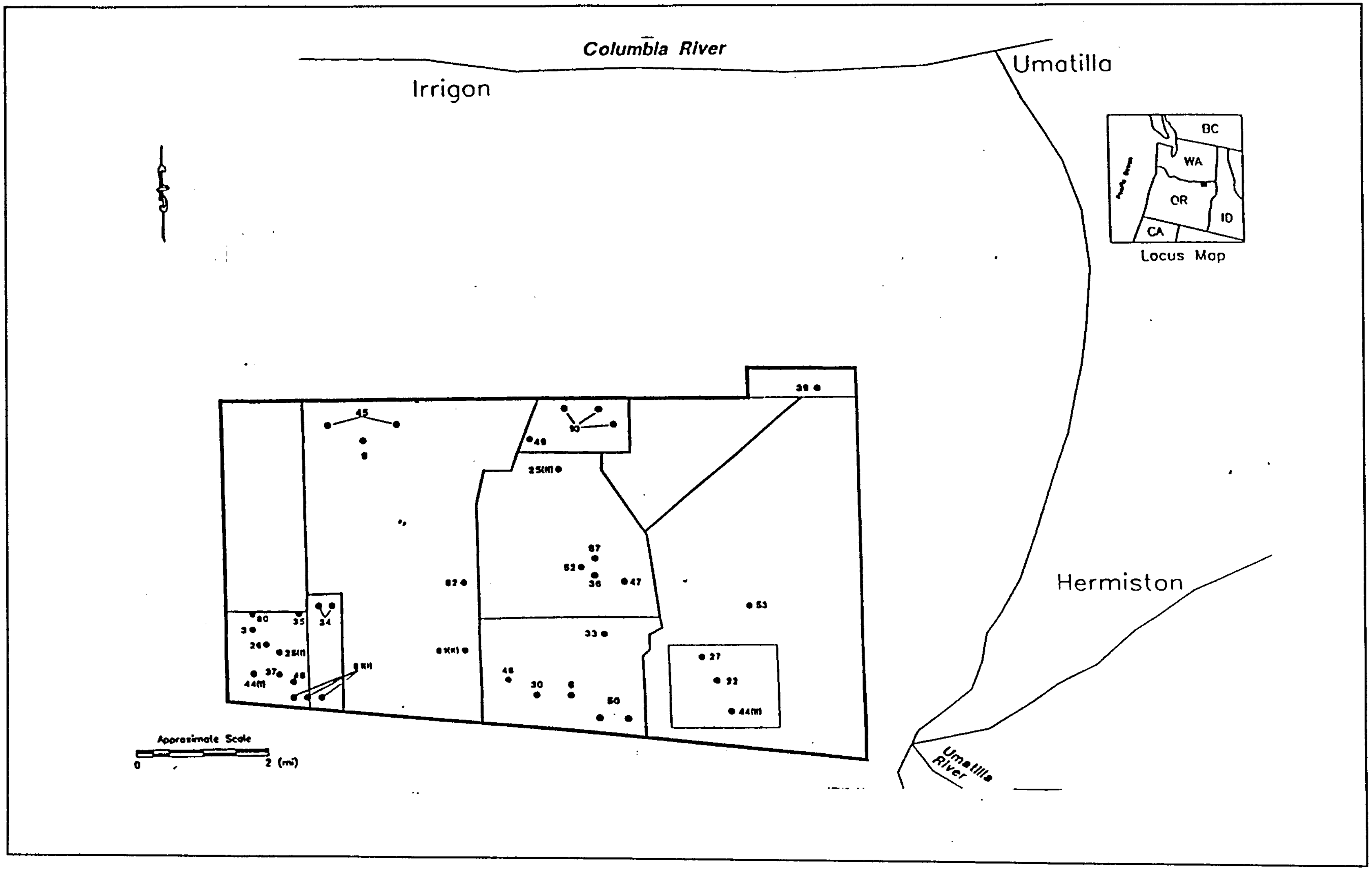

Figure 2. Location of operable units-5 at UMDA

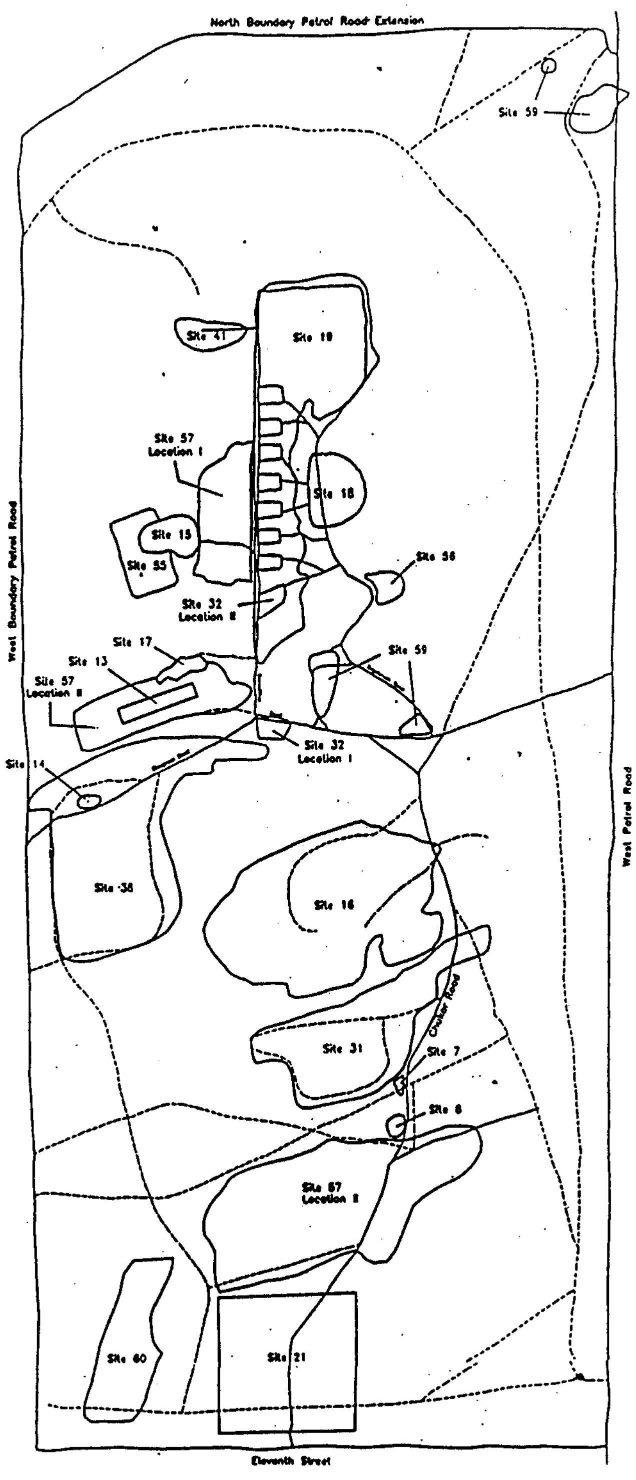

Figure 3. Location of ammunition demolition activity at UMDA

A study of alternatives for remediation of the explosive- and metal-contaminated soils found at the five identified sites focuses on alternatives using technologies that have been demonstrated to be effective and implementable. Technologies incorporated into the final remediation alternatives include excavation, chemical solidification/stabilization (CSS), and disposal at the UMDA landfill. The UMDA landfill is an unlined solid waste disposal facility located about 5 miles northeast of the Deactivation Furnace Site. Solidified materials are to be cured prior to placement in the disposal facility. A quality assurance/quality control (QA/QC) program will be developed to ensure that the solidified/stabilized materials are adequately treated prior to disposal.

Solidification/Stabilization

Congress enacted through the Hazardous and Solid Waste Amendments (HWSA) of 1984, under the Resource Conservation and Recovery Act (RCRA), new responsibilities on the handlers of hazardous waste. In particular, HSWA prohibits the continued land disposal of untreated hazardous waste [(RCRA sections 3004 (d)(1), (e)(1), (g)(5), 42 USC 6924 (d)(1), (e)(1), (g)(5))].

Of special issue under HSWA was the disposal of liquid waste. Specific language under HSWA bans the future land disposal of wastes containing free liquid in landfills. In addition, the utilization of adsorbents to remove free water is prohibited, and specifically stated is that materials used to treat free water must have evidence of a chemical reaction [(RCRA section 3004 (c)(1), USEPA 1982)]. In an effort to address the free liquids prohibition, the U.S. Environmental Protection Agency (USEPA) issued OSWER (the Office of Solid Waste and Emergency Response) Policy Directive 9487.00-2A (USEPA 1986a), which stipulates the development of an unconfined compressive strength (UCS) of 50 pounds per square inch (psi) as a measurement of meeting the chemical reaction, free liquid criterion.

Until approximately 1988, the primary goal of solidification/stabilization (S/S) was to meet the spirit of RCRA and to chemically treat free liquids. This changed with the development of waste treatment standards applied to the land disposal of waste under the USEPA's Land Disposal Restrictions. Language under RCRA required the USEPA to establish "levels or methods for treatment, if any, which substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste so that short-term and long-term threats to human health and the environment are minimized..." [RCRA sections 3004 (m)(1), and 42 USC 6924 (m)(1)]. In an effort to meet this congressional mandate, the USEPA promulgated specific treatment standards over the 1988-1990 time period for listed wastes. These treatment standards were developed under the guidelines of Best Demonstrated Available Technology.

Solidification/Stabilization is one technology that meets the demonstrated and available technology criteria; thus, it is utilized as one of the primary treatments used to establish treatment standards for metal-contaminated wastes (USEPA 1986b). Much of the experimental work performed for the establishment of these treatment standards, in conjunction with S/S, was conducted at the U.S. Army Engineer Waterways Experiment Station (WES) under the direction of the USEPA's Office of Research and Development. The general S/S protocol utilized for treatment standard development is outlined in a report entitled "An Evaluation of Stabilization/Solidification of Fluidized Bed Incinerator Ash (K048 and KO51)" (Bricka, Holmes, and Cullinane 1988).

Description

S/S is a process that involves the mixing of a contaminated soil with a binder material to enhance the physical and chemical properties of the soil and to chemically bind any free liquid (USEPA 1986c). Solidification is generally conceptualized as the enhancement of the physical characteristics of the waste material. This is accomplished by reducing exposed surface area, which in turn lowers the convective transport of contaminants from the waste. Solidification usually entails the incorporation of the waste into a solid matrix or monolith. In comparison, stabilization involves the reaction of the waste's hazardous waste constituents with the S/S reagents to immobilize or otherwise contain them. The stabilization process may be as simple as the addition of lime or a sulfide source to a heavy metal liquid waste, or may involve the development of special reagents specifically formulated to interact with the waste components. Most commercial vendors use a combination of solidification and stabilization to maximize the contaminant immobilization capability of the treated waste.

Several binder systems are currently available and widely used for the S/S of hazardous wastes (Cullinane, Jones, and Malone 1986). Typical binders include Portland cements, pozzolans, and thermoplastics. Most common S/S techniques are designed with either Portland cement or some type of pozzolan as the basic reagent. Portland cement is widely available, relatively economical, and well known to the general public as producing a very durable product. Pozzolans are siliceous materials that, when added to a source of lime, will go through a cementatious process similar to Portland cement but at a much slower rate. Fly ash and blast-furnace slags are common pozzolans that are generally considered as waste materials themselves. Kiln dust is also a pozzolan and a waste material. Kiln dust is generated from the production of lime or cement. Although the quality of kiln dust varies, kiln dust generally contains enough lime and fly ash to set simply with the addition of water.

In many cases, the S/S process is changed to accommodate specific contaminants and soil matrices. Generally, this is accomplished through the addition of admixtures. Soluble silicates, organophilic clays, activated carbon, as well as a host of other organic and inorganic chemicals are routinely used as admixtures for the immobilization of contaminants found in the soil. For

hazardous waste containing primarily metal contaminants, generally a cement or pozzolan binder makes up the bulk of the additive. Small quantities of admixture materials are added to the waste/binder mixture for a desired specific effect. Many of the proprietary processes marketed by the vendors of S/S are based upon admixtures.

Since it is not possible to consider all feasible modifications to an S/S process in this study, investigation of the S/S effectiveness can be narrowed to focus only on generic process types (such as Portland cement or lime/fly ash addition). The performance observed for a specific S/S system may vary widely from its generic type, but tailored processes generally are believed to perform better than the generic formulations. Typically, there is no need to evaluate proprietary S/S processes or admixtures if generic S/S processes prove to meet the goals of treatment. A comprehensive general discussion of admixtures and proprietary S/S processes are given in Malone and Jones (1979), Malone, Jones, and Larson (1980), and USEPA (1986c).

S/S treatment systems

After careful consideration, it was decided to limit this investigation to two S/S systems using generic binders. Selection of the binders was based on economic factors, historical treatment effectiveness, and binder availability. The binders selected for evaluation in this study include the following:

a. Portland Type I cement.

b. Portland Type I cement/Type F fly ash.

Objective and Scope of Study

The purpose of the treatability program for the metal- and explosive-contaminated soils is to provide the U.S. Army Engineer District, Seattle, technical assistance in the evaluation of S/S techniques that are capable of treating UMDA soils. Specific objectives are listed below:

a. Assess whether contaminated soils containing maximum levels of heavy metals found at the sites require S/S to meet toxicity characteristic leaching procedure (TCLP) criteria.

b. Assess whether contaminated soils containing maximum levels of heavy metals and explosives found at the sites require S/S to meet TCLP criteria.

c. Determine effective S/S techniques and formulations that can be applied to contaminated soils to reduce contaminant leaching and meet TCLP criteria.

d. Evaluate the physical and chemical properties of the solidified/stabilized soils to determine if S/S techniques will substantially reduce the amount of contaminants in the leachate and improve the physical handling properties of the soil.

e. Determine the S/S processes to be used in developing a Government cost estimate for S/S treatment and disposal.

Treatment goals for the contaminants of concern for the TCLP leachate were established by the Seattle District for the treatability study. These treatment goals are presented in Table 1.

Table 1
Proposed Treatment Goals for Treatability Study for TCLP for UMDA Soils

	mg/ℓ														
Soil	**Sb**	**As**	**Ba**	**Be**	**Cd**	**Cr**	**Pb**	**RDX**	**TNT**	**TNB**	**DNB**	**2,4-DNT**	**HMX**	**NB**	**TETRYL**
2,236	na[1]	na	na	na	1.0	5.0	5.0	na	na	na	na	na	na	na	na
15	0.146	5.0	100.0	0.004	1.0	5.0	5.0	0.070	0.280	1.8	0.40	0.130	35.0	2.0	40.0
19	0.146	5.0	100.0	0.004	1.0	5.0	5.0	0.070	0.280	1.8	0.40	0.130	35.0	2.0	40.0
31	na	na	na	na	na	na	na	0.070	0.280	1.8	0.40	0.130	35.0	2.0	40.0

[1] na: Denotes that these compounds were not of concern for the soil sample.

2 Methods and Materials

General Approach to Investigation

This investigation was conducted in the five primary phases summarized below.

a. *Phase I: Sample collection.* Contaminated soils were collected from Sites 22 and 36 of the Miscellaneous Sites OU-5 and Sites 15, 19, and 31 of the ADA for the S/S study. The five soils were packed in 5-gal containers and shipped to WES for the S/S study.

b. *Phase II: Homogenization.* The soils were homogenized upon receipt of the samples at WES. All samples were first passed through a shaker sieve to remove rocks and debris larger than 0.50 in. The S/S study was conducted on the soil size fraction that passed the 0.50-in. sieve screen.

c. *Phase III. Preliminary testing.* Tests were performed to determine the appropriate amount of binder and water to be added to the soils for the detailed evaluation. Physical tests were performed on the samples to evaluate strength development for each mixture. Chemical analyses were performed on all samples to determine the contaminant leachability during the TCLP test.

d. *Phase IV. Detailed evaluation.* Based on the information from preliminary testing, samples were prepared for detailed evaluation. Physical tests and contaminant leach tests were performed on the samples to evaluate the effectiveness of S/S on the soil and contaminant leachability.

e. *Phase V: Data analysis and report preparation.* Test data were consolidated and evaluated.

Sample Collection

The materials of interest were contaminated soils collected from five locations at two sites. Two soils were collected from the Miscellaneous Sites OU-5 and three soils from the sites at the ADA. Contaminants of interest for the two soils from the Miscellaneous Sites OU-5 were cadmium, chromium, and lead. Contaminants of interest for the three soils collected from the ADA were heavy metals and explosive compounds. Five soils, Soil 22 and Soil 36 (OU-5) and Soil 15, Soil 19, and Soil 31 (ADA), were collected and shipped to WES in sixty-four 5-gal containers.

Prior to the homogenization of the soils, each soil was passed through a 0.50-in. screen to remove any large debris from the soil. The soil that passed the 0.50-in. screen was used for the treatability study. A total of four soil samples were evaluated for the S/S study. Once the soils were received at WES, Soils 22 and 36 were mixed to form one soil identified as Soil 2236. The mixing of the two soils was performed at the request of the Seattle District personnel since the two soils only contained metal contaminants and would be mixed for the treatment of the soils onsite. The three soils from the ADA, Soil 15, Soil 19, and Soil 31, were homogenized individually for the S/S study. Homogenization of the soils was accomplished by passing the soil through a Gilson model SP-1 soil splitter. Each 5-gal bucket for each soil was passed through the splitter three times to obtain a representative sample for the S/S study. Once the soils were mixed, they were split and labeled as Replicates A or B. Moisture content was performed on the homogenized soil samples as an indicator of homogeneity. These results are presented in Appendix A.

Untreated Soil Characterization

Chemical tests

Bulk analysis. The two replicates of each of the untreated soils were subjected to chemical analysis to determine the contaminant concentrations present in each soil. Bulk chemical metal and explosive analyses were performed on the soils prior to initiation of leaching tests.

Toxicity characteristic leaching procedure (TCLP). The two replicates of each soil were subjected to the TCLP extraction procedure to determine the hazardous characteristics of the soil and to measure the contaminant mobility as defined by the USEPA (USEPA 1986a). This method consisted of crushing the sample to pass a 9.5-mm standard sieve. The crushed sample was placed in a 0.5 N acetic acid extract or an acetate buffer extract, depending on the buffering capacity of the soil, at a 20:1 liquid-to-solids ratio. The soil and extract were placed in 1-gal glass jars and tumbled end over end for 18 hr. At the completion of this period, the sample was filtered using a Whatman GF/F 0.75-μm filter. Only a single extraction is performed for the test. The filtered

extracts were placed in precleaned bottles and stored at 4 °C prior to analysis. Each extract for each soil was analyzed for the contaminants of concern for that soil.

Physical tests

Physical characteristics of the untreated soils were evaluated using the following test procedures. Test specimens were prepared in accordance with the requirements of the test method discussed below.

Moisture content. The moisture content for each of the two replicates (A and B) for each soil were conducted according to modified ASTM D-2216 (American Society for Testing and Materials (ASTM) 1992a). This method was modified by drying the sample to constant weight at 60 °C. Lower temperatures are utilized with contaminated materials to avoid removing large volumes of the contaminants and to reduce the release of hydrated water from the sample. The moisture content measurements were used to calculate the dry weight of each sample.

Bulk density. The bulk density of each of the two replicates for each soil were conducted according to ASA 13 (American Society of Agronomy (ASA) 1965). This test was performed on the untreated samples by loosely placing a known mass of soil into a mold of known volume. This density represents the uncompacted laboratory density of the soil as it was used in the S/S treatability study. The laboratory bulk density is not the in situ density, which is measured in the field. Laboratory density loosely approximates the field density of uncompacted excavated soil. The bulk densities were calculated using the mass and volume data and were reported in units of pounds per cubic foot.

Grain-size analysis. The grain-size distribution for each replicate for each soil was conducted according to EM 1110-2-196 Appendix VII (U.S. Army Corps of Engineers 1970). This method uses a combination of sieving and a hydrometer for analysis. The soils were visually inspected during homogenization for debris. All particles larger than 0.50 in. were removed from the soils during homogenization, and the size fraction less than 0.50 in. was subjected to the grain-size analysis.

Atterburg limits. The Atterburg limits for each replicate for each soil was conducted according to ASTM D-4318 (ASTM 1992a). This test is used to determine the water content at the boundaries between the plastic and liquid states of the soils. The plastic limit is the water content at which the soil will start to crumble when rolled into a 3-mm thread under the palm of the hand. The liquid limit is defined as the lowest water content at which the soil will flow as a viscous liquid.

Proctor density. The Proctor density for each replicate for each of the four soils was conducted according to ASTM D-698 (ASTM 1992b). This procedure is used to determine the relationship between water content and the

dry unit weight of the solids compacted with an effort of 12,400 ft-lb/ft^3. Optimal Proctor density is the maximum density (reported as pounds per cubic foot) that can be achieved at 12,400 ft-lb/ft^3. The soil moisture content at which the maximum Proctor density occurs was also measured.

Unconfined compressive strength. The UCS was determined for the two replicates of each soil. The UCS measurements were conducted according to modified ASTM C-109 (ASTM 1992a). The main deviation from this method was that the untreated samples were prepared by adding water to the soils at 85 percent of optimal moisture required for maximum compaction and compacting the soils in the 2-in. cube molds using the compaction effort as described in the Proctor density section. A special compaction hammer was prepared with a 1.8- by 1.0-in. rectangular head and a drop weight of 2.49 kg to deliver this compactive effort. The samples were aged for 7 days in an environment controlled at 23 °C ± 2 °C and 95-percent ± 5-percent relative humidity prior to testing. After removal from the mold, the surface area of each sample was determined using a Fowler Max-Cal Caliper. The cubes were placed in plastic bags; while in the bag, each cube was subjected to a compressive force until the cube fractured. A Tinius Olsen Super-L compressive apparatus was used to supply this force and indicate the compressive strength at which the cubes fractured. The UCS of each cube was reported as the force required to fracture the cube in pounds per square inch of surface area.

Resistance to penetration. The Cone Index (CI) determination was performed for each replicate of each soil and was conducted according to TM 5-540 (Headquarters, Department of the Army 1971). The CI measures the resistance of a material to the penetration of a 30-deg right circular cone. The CI value is reported as force per unit surface area (pounds per square inch) of the cone base required to push the cone through a test material at a rate of 72 in./min. Two cones are available for this test: (a) the standard WES cone having an area of 0.5 sq in. and (b) the airfield penetrometer having a base area of 0.2 sq in. Because of its smaller cone, the airfield penetrometer can measure larger CI values. It was convenient to use the standard WES cone penetrometer on materials with a CI up to 300 psi. The maximum CI value that can be measured by the airfield penetrometer is 750 psi; therefore, materials having CI values greater than 750 psi are reported simply as >750 psi.

Specific gravity. The specific gravity (SG) for each of the replicates for each soil was determined according to ASTM D-854 (ASTM 1992b). Specific gravity is the ratio of the mass of a unit volume of the soil at a stated temperature to the mass in air of the same volume of gas-free distilled water at a stated temperature. SG is typically utilized as an indication of the soil particle density. SG measurements are unitless but are generally referenced to the density of water.

Preparation of Test Specimens

Two processes were used to solidify/stabilize the soils from the Miscellaneous Sites OU-5 and the ADA and were differentiated by the type of binder material used in the process. The two processes used for this study were Portland cement and Portland cement combined with Class F fly ash. A compositional analysis and a chemical analysis of binders used in this study are presented in Tables 2 and 3, respectively.

Table 2
Compositional Analysis of Binders

Compositional Analysis	Cement, Type I, %	Fly Ash, Class F, %
SiO_2	20.47	49.67
Al_2O_3	5.40	29.15
Fe_2O_3	3.58	7.11
CaO	64.77	1.26
MgO	0.87	1.43
SO_3	2.73	0.23
Insoluble residue	0.17	70.70[1]
Moisture loss	0.43	0.12[2]
Loss on ignition	0.96	4.07
TiO_3	0.28	0.20
Mn_2O_3	0.06	0.00
P_2O_5	0.28	1.00
Total alkali		
Na_2O	0.12	0.23
K_2O	0.28	2.33
Na	0.05	0.10
K	0.11	0.97
Total as Na_2O	0.30	1.76
Acid soluble alkali		
Na_2O	0.12	0.06
K_2O	0.28	0.50
Na	0.05	0.03
K	0.11	0.21
Water soluble alkali		
Na_2O	0.018	0.050
K_2O	0.139	0.105
Na	0.0075	0.0210
K	0.0577	0.0440

[1] Insoluble residue includes SiO_2.
[2] Free water.

The S/S process involves the addition of water and binder material to the waste followed by a mixing and a curing period. A flowchart of S/S processing is shown as Figure 4.

WES prepared generic chemical S/S formulations for two binder systems (cement and cement/fly ash). An initial screening test (IST) was used to

Table 3
Chemical Analysis of Binders

Chemical Analysis	Cement, Type I, mg/kg	Fly Ash, Class F, mg/kg
Si	95,700	32,400
S (total)	10,800	31,200
Ti	1,400	600
P	900	200
Sb	<1.77	13.3
As	13.1	172
Be	2.13	28.9
Cd	0.284	1.01
Cr	61.3	139
Cu	14.9	196
Pb	2.13	57.7
Hg	<0.100	<0.100
Ni	25.9	190
Se	<17.7	<19.5
Ag	<3.54	<3.90
Tl	<10.6	13.6
Zn	41.8	211
Al	23,100	150,000
Ba	178	1,350
Ca	454,000	12,000
Cd	10.6	77.2
Fe	25,400	50,700
Mg	5,460	6,040
Mn	503	156
Na	1,270	2,740
Sn	195	118
V	55.6	351

narrow the range of binder-to-soil ratios (BSRs) and water-to-soil ratios (WSRs) necessary for detailed S/S treatment of the four Umatilla soils. All of the soils required the addition of water to ensure the hydration of the binder material. The IST involved mixing binder, water, and soil in a K455S Hobart mixer at two WSRs (by weight). Water ratios of 0.1 and 0.3 were used for

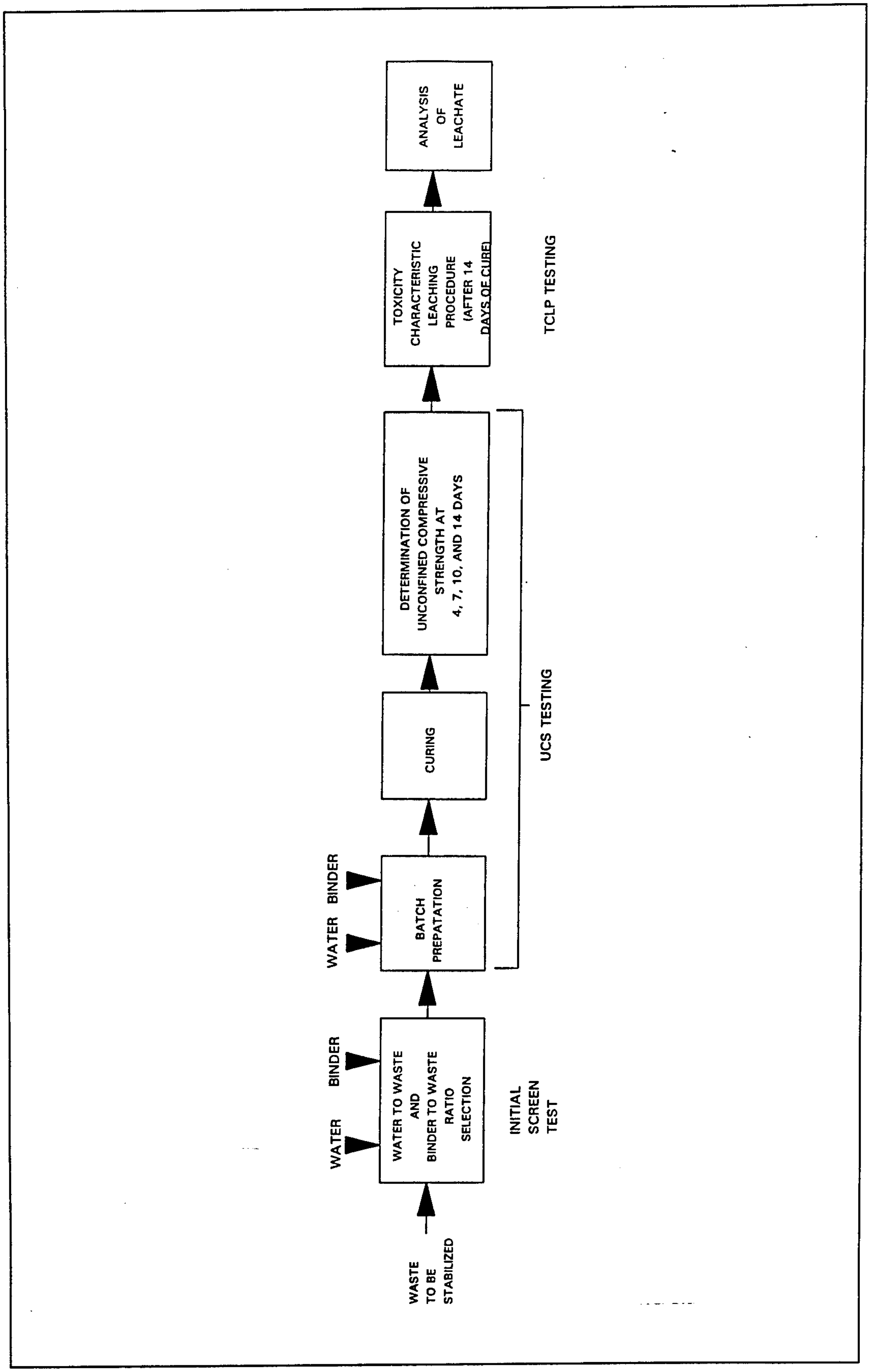

Figure 4. Schematic flowchart for stabilization porcessing

both binder systems. These ratios were chosen on a basis of previous experience of the testing personnel and the moisture content of each of the four soils. A total of two binders, two BSRs and two WSRs, for a total of eight evaluations, were evaluated for each soil in the IST phase of the study as shown in Table 4.

Table 4
Matrix of Specimens Prepared for Initial Waste/Binder Screening

Ratio	Indicated Water/Soil Ratio 0.1	Indicated Water/Soil Ratio 0.3
Binder: Cement		
Cement		
0.1	1	1
0.5	1	1
Binder: Cement/Fly Ash		
Cement/Fly Ash		
0.1/0.1	1	1
0.4/0.4	1	1

After each formulation was mixed for 10 min, the mixture was placed in 4-in.-diam by 4-in.-height cylindrical molds and 3-in.-diam by 3-in.-height cylindrical plastic molds. These mixtures were either poured into the molds and vibrated on a Syntron model VP61D1 vibration table or compacted in the molds using the standard Proctor effort as described previously under the Proctor density section. The samples were placed in a controlled environment at 23 °C ± 2 °C and 95-percent relative humidity ± 5 percent until needed for testing.

Determination of the optimal WSRs and BSRs was based on the results of the CI performed on the initial screening test samples during a 48-hr curing period. CI measurement, as described in soil characterization, was performed on these samples at 2, 4, 8, 24, and 48 hr after curing.

After the IST samples had cured for 48 hr, the samples were subjected to the TCLP. The TCLP extracts were analyzed for the primary contaminants of concern for each soil. The results of the IST, CI, and TCLP tests were used to select the WSR and narrow the range of BSRs that were utilized in the detailed evaluation portion of this study.

Detailed Evaluation Testing

Sample preparation

Four formulations of cement and four formulations of cement/fly ash were prepared in duplicate for each soil during the detailed S/S evaluations.

Solidified/stabilized specimens were prepared by mixing water and binders with the contaminated soil in a Hobart C-600 mixer. The soil and additives were mixed for 5 min, the sides of the container were scraped to remove adhering material, and the mixture was mixed an additional 5 min. When mixing was complete, the sample was subjected to the paint filter test (USEPA 1986b) to determine if free liquid was present in the mixture.

Mixtures that were determined not to have free water were poured into molds. A variety of specimens were prepared based upon the various test protocol. To aid in removing test specimens from the molds, a light coat of grease was applied to the molds used to cast the UCS specimens. Specimens used for the TCLP were placed in ungreased molds to avoid chemical contamination from the grease. Immediately after the additive/water/soil mixtures were placed in the molds, they were vibrated on a Sentron model VP61D1 vibration table to remove voids. Some of the mixtures were viscous so that vibration was an ineffective method for removing voids. These specimens were tamped according to ASTM C 109-86 (ASTM 1990) using a model CT-25A tamper.

The molded solidified/stabilized materials were cured in the molds at 23 °C and 98-percent relative humidity for a minimum of 24 hr. Specimens were removed from the molds when they developed sufficient strength to be free-standing and were cured under the same temperature and relative humidity conditions until required for further testing. After the solidified/stabilized soils had cured for 14 days, the physical and chemical properties of the S/S soil were determined.

Evaluation methods

The success of an S/S process can be evaluated in a number of ways. For this study, eight physical tests and one chemical test were used. The following sections describe the method protocol for physical and chemical testing used for the detailed evaluation phase of this study.

Unconfined compressive strength. The unconfined compressive strength of the solidified/stabilized soil samples was determined using the method specified previously in the Untreated Soil Characterization section of this report. UCS testing was performed on the CSS cubes after they had cured for 5, 10, and 14 days. Two cubes for each binder and each formulation and each replicate (A and B) were tested at these curing periods. A total of 64 cubes were prepared and evaluated for UCS.

Set time. The set time is defined as the time required to develop sufficient rigidity following mixing to resist the penetration of a standard rod or needle. Set time for the CSS samples was evaluated using the CI as described in the Untreated Soil Characterization section of this report. Measurements were taken on samples after they had cured 2, 4, 8, 24, and 48 hr. CI tests were

performed in triplicate for each binder, each formulation, and each replicate (A and B).

Slump test. Workability of the treated specimens was evaluated using the slump test, ASTM method C 143 (ASTM 1987). Slump was determined by measuring the vertical displacement of the center of the treated sample after 2.5 min. Slump measurements were performed for each binder formulation for each soil.

Bulk density. Two bulk density determinations for the CSS samples were performed for each binder, each formulation, and each replicate (A and B). A total of 32 cubes were tested for the soil for bulk density after they had cured for 14 days under a controlled environment. Density determinations were performed according to the procedures previously described under the Untreated Soil Characterization section of this report. Estimates of the percentage volume increases resulting from S/S were determined by comparing the volume of a known unit weight of contaminated soil before and after S/S. Equations 1 through 3 were used in calculating the percent volumetric change for each solidified/stabilized soil.

For the untreated soil,

$$V_1 = \frac{W_s}{D_1} \tag{1}$$

where

V_1 = volume of soil

W_s = weight of soil

D_1 = Proctor density of untreated soil

For the solidified/stabilized soil,

$$V_2 = \frac{(W_s + (R \times W_s))}{D_2} \tag{2}$$

where

V_2 = volume of binder to soil

R = binder-to-soil ratio (BSR)

D_2 = bulk density of soil and binder

$$\% \ Volumetric \ Change = \frac{(V_2 - V_1)}{V_1} \tag{3}$$

Bleed water. Bleed water is defined as the relative quantity of mixing water that will bleed from a freshly mixed concrete. The amount of bleed water produced in each formulation selected for detailed evaluation was measured using ASTM Method C 232 (Bleeding of Concrete ASTM 1987). To determine if the mixtures produced bleed water, samples were visually inspected to determine if a water layer was present. ASTM method C-232 method A was used to measure the quantity of this bleed water.

Cracking. There are no known standard test procedures for measuring the degree of cracking. The sample specimens were visually inspected for cracks. Development of cracks is considered to be detrimental to solidified samples. The formation of cracks increases the surface area of the sample. One of the purposes of the S/S process is to decrease the surface area of the waste by the formation of a monolith. The formation of cracks increases the potential for water infiltration by increasing the waste's surface area, thus increasing the potential for contaminant leaching.

Moisture content. Three moisture content determinations for the solidified/stabilized samples were performed for each soil, each binder, each formulation, and each replicate (A and B). A total of 48 samples for each soil were crushed to pass a 9.5-mm seive and tested for moisture content after they had cured for 14 days under a controlled environment. Moisture content determinations were performed following the procedures previously described under the Untreated Soil Characterization section of this report.

Specific gravity. Specific gravity was evaluated for each replicate (A and B) for each formulation for each binder system for each soil. The method followed is outlined in the Untreated Soil Characterization section of this report.

Toxicity characteristic leaching procedure. TCLP extractions were performed on the solidified/stabilized samples after 14 days of curing for each soil, each binder, each formulation, and each replicate. The TCLP extracts were analyzed for the contaminants of concern for each soil. The TCLP was performed according to the test method previously described in the chemical tests for the Untreated Soil Characterization section.

3 Results of Contaminant Mobility and Physical Testing

Untreated Soil Characterization

As discussed in the Methods and Materials section of this report, samples that were used to characterize the untreated soils were subjected to a battery of physical and chemical tests. The results of the physical tests are summarized in Tables 5 and 6. The raw physical test results for the untreated soil characterization are presented in Appendix A. The purpose of this initial characterization is twofold. First, engineering properties of the soils were measured to provide data that describe the soils, and, secondly, baseline data are collected for the untreated soils to provide a basis of comparison for assessing improvments/detriments of S/S application to UMDA soils.

Although little discussion is needed for Tables 5 and 6, it should be noted that the Atterburg limit for the soils could not be performed. Since the soils contained such a large amount of sand, the liquid limit and plastic limit for the soils could not be determined. Also, the UCS for the soils could not be performed because the samples crumbled when removing them from the mold and were documented as below the 50-psi criteria established by the USEPA (USEPA 1986a). Thus, the soil cannot be solidified (achieve physical integrity) simply by compaction at the optimal moisture content.

Bulk chemistry

A bulk chemical analysis was performed on the untreated soils to determine the total concentration of contaminants. Tables 7 and 8 present the results of the bulk chemical analysis of the four soils tested in this study. Soil 2236 had average concentrations of 1,200 mg/kg of cadmium, 185 mg/kg chromium, and 650 mg/kg lead. Cadmium, chromium, and lead were the only metals analyzed in Soil 2236. All explosives that were analyzed for bulk chemistry were below the detection limits except for RDX (cyclotrimethylenetrinitramine) and

Table 5
Average Results of Physical Tests Conducted on Untreated Umatilla Soils

Replicate	Moisture Content, %	Bulk Density lb/ft^3	Proctor Density lb/ft^3	UCS psi	Specific Gravity	Cone Index psi
Soil 2236						
A	6.0	114	139.3	0	2.69	145
B	6.0	120	139.7	0	2.67	145
Soil 15						
A	5.3	77	129.6	0	2.74	200
B	5.1	72	130.3	0	2.73	200
Soil 19						
A	8.3	93	135.9	0	2.78	175
B	8.0	94	133.6	0	2.76	190
Soil 31						
A	6.0	102	125.5	0	2.69	100
B	6.0	101	126.8	0	2.70	90

Table 6
Average Results of Grain-Size Analysis of Untreated Umatilla Soil

Replicate	Gravel >4.75 mm %	Sand 4.75 - 0.106 mm, %	Fines <0.106 mm, %	Unified Soil Classification
Soil 2236				
A	6.5	77.0	16.6	Silty Sand (SM)
B	6.7	76.4	16.9	Silty Sand (SM)
Soil 15				
A	2.2	79.8	18.0	Silty Sand (SM)
B	2.3	81.2	16.5	Silty Sand (SM)
Soil 19				
A	7.5	73.4	19.1	Silty Sand (SM)
B	7.8	72.7	19.5	Silty Sand (SM)
Soil 31				
A	7.6	81.5	10.9	Silty Sand (SM)
B	7.3	82.3	10.4	Silty Sand (SM)

Table 7
Results of Metals for Bulk Chemistry for Four Untreated UMDA Soils

Replicate	mg/kg								
	As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
Soil 2236									
A	NA[1]	NA	NA	1,200	NA	200	700	NA	NA
B	NA	NA	NA	1,200	NA	170	600	NA	NA
Soil 15									
A	2.5	210	0.18	31.0	5.8	38.0	180	3.1	<0.20
B	2.4	240	1.19	29.0	5.4	35.0	170	3.6	<0.20
Soil 19									
A	15.0	1,300	NA	55.0	NA	13.0	3,660	12.0	NA
B	4.8	1,300	NA	68.0	NA	13.0	3,300	93.0	NA
Soil 31									
A	NA	NA	NA	0.31	NA	6.6	43	NA	NA
B	NA	NA	NA	0.29	NA	8.1	16	NA	NA

[1] NA: Denotes that the soil was not analyzed for this compound.

TNB (trinitrobenzene). RDX and TNB had average concentrations of 0.096 and 0.083 mg/kg, respectively.

Results of bulk chemistry for Soil 15 show that cadmium and lead are present at average concentrations of 30 and 175 mg/kg, respectively. Explosive compounds were present in higher concentrations in Soil 15 than in any of the other three soils. Average concentrations of HMX, RDX, TNB, and TNT found in Soil 15 were 458.5, 2,950, 50.25, and 3,880 mg/kg, respectively.

The results of bulk chemistry for Soil 19 showed that cadmium, lead, selenium, and barium were present in the highest concentrations. Average concentrations for cadmium, lead, selenium, and barium were 61.5, 3,450, 52.5, and 1,300 mg/kg, respectively. Explosive compounds were present in Soil 19 with TNT having the highest average concentration of 86.1 mg/kg.

The results of bulk chemistry for Soil 31 indicated that low levels of metals and explosives were present in the soil sample. Only three metals were analyzed for bulk chemistry, cadmium, chromium, and lead. Of these three metals, lead was present in the highest concentration with an average

Table 8
Average Results of Explosive Compounds for Four Untreated UMDA Soils

Replicate	mg/kg									
	HMX	RDX	TNB	DNB	Tetryl	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT
Soil 2236										
A	<2.20	0.08	0.105	<0.25	<0.65	<0.65	<0.25	<0.25	<0.26	<0.25
B	<2.20	0.115	0.06	<0.25	<0.65	<0.65	<0.25	<0.25	<0.26	
Soil 15										
A	447	2,870	52.5	<0.25	<0.65	3,990	<0.25	<0.25	<0.26	<0.25
B	470	3,030	48.0	<0.25	<0.65	3,770	<0.25	<0.25	<0.26	0.26
Soil 19										
A	5.8	13.1	12.9	<0.25	<0.65	109	<0.25	0.335	<0.26	0.020
B	7.3	15.1	13.1	<0.25	<0.65	63.1	<0.25	0.298	<0.26	0.135
Soil 31										
A	<2.20	0.11	<0.25	<0.25	<0.65	0.120	0.115	<0.25	<0.26	<0.25
B	0.125	0.36	<0.25	<0.25	<0.65	0.836	0.135	<0.25	<0.26	<0.25

concentration of 29.5 mg/kg. Explosives were present in the soil sample at low levels and were not of concern. HMX, RDX, TNT, and 4A-DNT were the only explosive compounds detected in the sample.

TCLP

TCLPs were performed on each of the replicates (A and B) for each soil. Tables 9 and 10 present the results of the TCLPs performed on the untreated soils.

Table 9
Results for Metals for TCLP for Four Untreated UMDA Soils

Replicate	mg/ℓ								
	As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
Soil 2236									
A	NA[1]	NA	NA	2.5	NA	0.17	0.58	NA	NA
B	NA	NA	NA	9.0	NA	0.38	1.90	NA	NA
Soil 15									
A	<0.003	6.6	<0.0006	0.44	0.035	0.35	0.35	0.012	0.002
B	<0.003	18.0	<0.0006	0.42	0.051	0.11	1.10	0.019	<0.002
Soil 19									
A	0.009	10	NA	3.0	NA	<0.013	13	1.1	NA
B	0.006	16	NA	1.3	NA	<0.013	125	0.82	NA
Soil 31									
A	NA	NA	NA	0.002	NA	<0.013	0.01	NA	NA
B	NA	NA	NA	0.002	NA	<0.013	0.006	NA	NA

Note: Shaded area denotes that sample failed TCLP and performance criteria for the study.
[1]NA: Denotes that sample was not analyzed for this compound.

TCLP metals analysis for Soil 2236 showed cadmium was the only metal to fail the TCLP. The average concentration of cadmium found in the TCLP leachate was 5.75 mg/ℓ, above the TCLP limit of 1.0 mg/ℓ. Chromium and lead were below the TCLP limit of 5.0 mg/ℓ for the untreated soil. Since cadmium failed the TCLP, it also failed to meet the performance criteria of 1.0 mg/ℓ established for this study. The TCLP analysis for the untreated Soil 15 shows that all metals evaluated for the TCLP passed the TCLP and the performance criteria established for the study. All metals tested for the TCLP

Table 10
Results of Explosive Compounds for TCLP for Four Untreated UMDA Soils

Replicate	mg/ℓ									
	HMX	RDX	TNB	DNB	Tetryl	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT
Soil 2236										
A	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
B	<0.02	0.02	<0.26	<0.02	<0.05	<0.025	<0.02	<0.02	<0.02	<0.02
Soil 15										
A	3.03	24.6	0.488	<0.02	<0.05	18	0.144	0.201	<0.02	0.01
B	2.56	17.0	0.368	<0.02	<0.05	11.3	0.038	0.070	<0.02	<0.02
Soil 19										
A	0.135	17.0	0.368	<0.02	<0.05	11.3	<0.02	0.01	<0.02	<0.02
B	0.477	0.165	0.041	<0.02	<0.05	4.64	0.017	0.04	<0.02	<0.02
Soil 31										
A	<0.02	0.013	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
B	<0.02	0.014	<0.025	<0.02	<0.05	<0.0236	<0.02	<0.02	<0.02	<0.02

Note: Shaded area denotes sample failed to meet performance criteria for the study.

for the untreated Soil 19 passed the TCLP except for cadmium and lead. The TCLP limit for cadmium and lead for the TCLP is 1.0 and 5.0 mg/ℓ, respectively. The average cadmium and lead concentrations in the TCLPs for Soil 19 were 2.15 and 19.0 mg/ℓ, respectively. Since these two metals failed the TCLP, they also failed to meet the performance criteria established for this study. All three metals tested for Soil 31 passed the TCLP; therefore, they met the performance criteria for the study.

The TCLP was also performed on the four soils for explosive compounds. There were no explosive compounds detected in the TCLP leachate for Soil 2236. The TCLP leachate for Soil 19 indicated that explosive compounds were leached from the untreated soil in concentrations that failed to meet the performance criteria established for this study. Although many compounds were detected in the TCLP leachate, only two explosive compounds were above the performance criteria. These two explosive compounds were RDX and TNT. The average concentrations of RDX and TNT found in the TCLP leachate were 20.8 and 14.65 mg/ℓ, respectively. The performance criteria for these two compounds for this study were 0.070 mg/ℓ for RDX and 0.280 mg/ℓ for TNT. As with Soil 15, Soil 19 showed similar results for the TCLP. Some explosive compounds were detected in the TCLP leachate, but only RDX and TNT failed to meet the performance criteria. The average concentrations for RDX and TNT for the TCLP for Soil 19 were 8.58 and 7.97 mg/ℓ, respectively. The TCLP leachate for Soil 31 met the performance goals for the study for the explosive compounds. The only explosive compound that was detected in the TCLP leachate was RDX at a concentration of 0.0135 mg/ℓ.

Initial Screening Test Results

The average results of the IST for the four soils are presented in Figures 5-12. Figures 5-12 are plots of cure time versus CI for all soil and binders evaluated in the IST. The individual results of the IST tests are presented in Appendix B.

Figure 5 presents the IST CI for Soil 2236 using varying cement BSRs and varying WSRs. As can be seen in Figure 5, all samples achieved the maximum CI of 750 psi after 24 hr of cure except the ratio of 0.1 cement/0.3 water. It was observed that these samples were extremely wet when mixing and were poured into the molds for testing. The 0.1 cement/0.3 water sample had free water on the top of the sample for the 2- and 4-hr CI test. The free water had dissipated from the sample at the 8-hr cure time.

Figure 6 presents the IST CI for Soil 2236 using varying cement/fly ash BSRs and varying WSRs. Figure 6 shows that all samples achieved the maximum CI of 750 psi after 24 hr of cure except the ratio of 0.1 cement/0.1 fly ash/0.3 water. This sample was extremely wet and had free water on the top

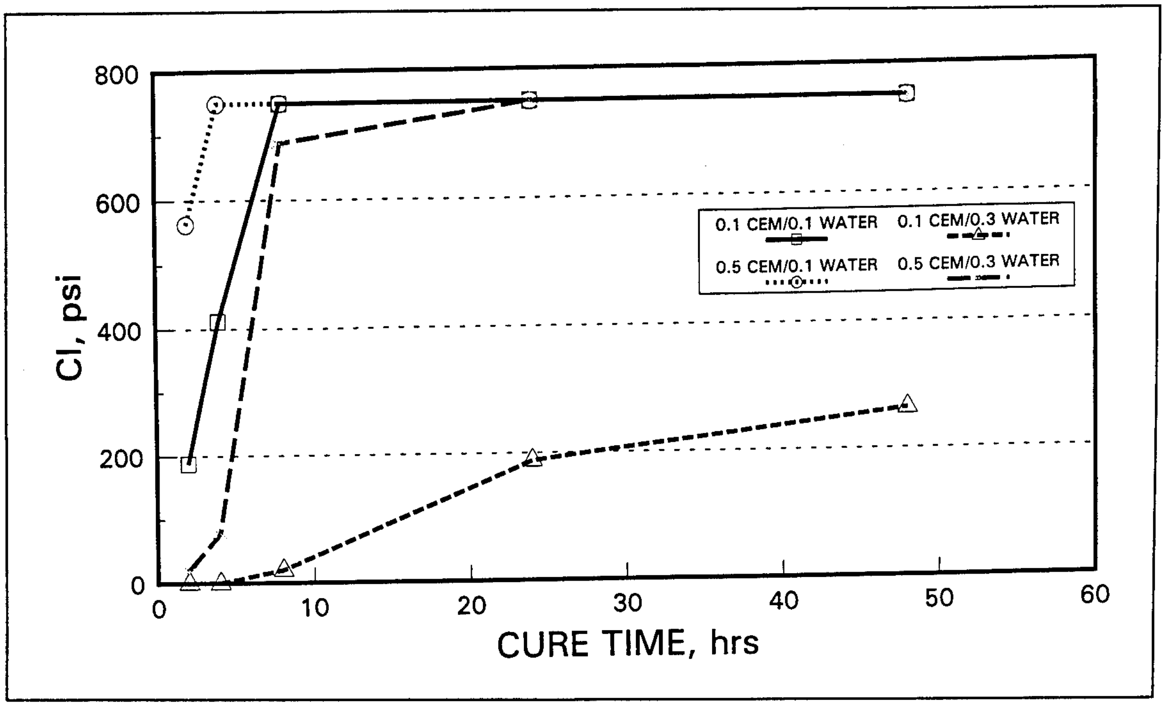

Figure 5. Average IST CI results for Soil 2236 for cement BSRs

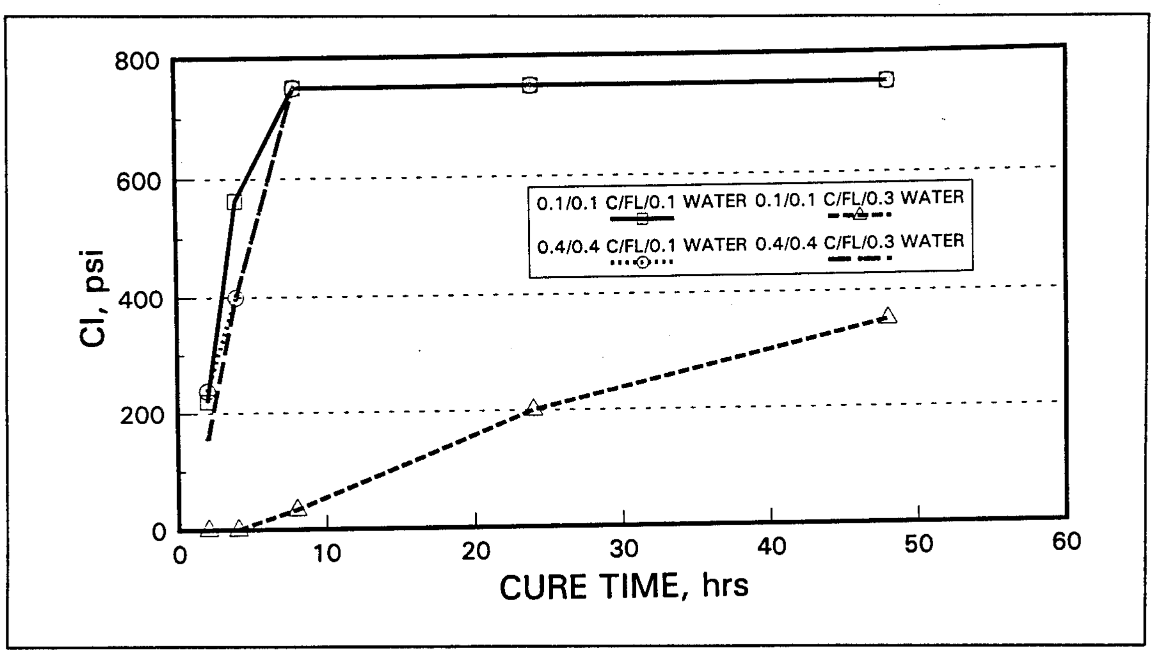

Figure 6. Average IST CI results for Soil 2236 for cement/fly ash BSRs

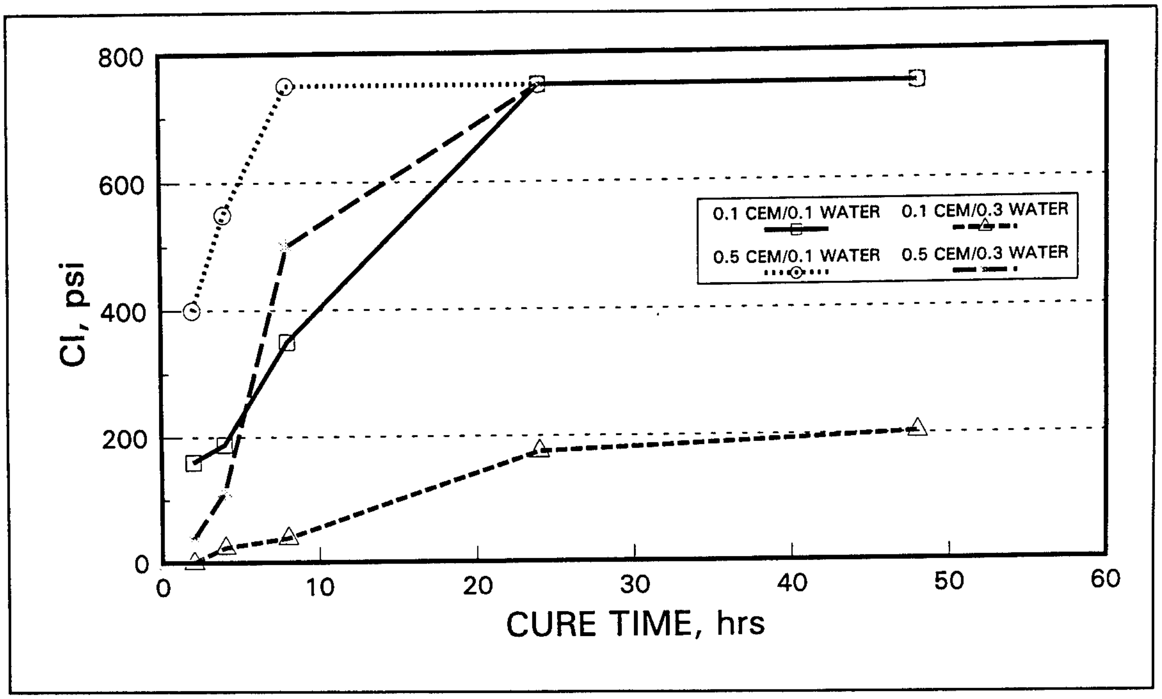

Figure 7. Average IST CI results for Soil 15 for cement BSRs

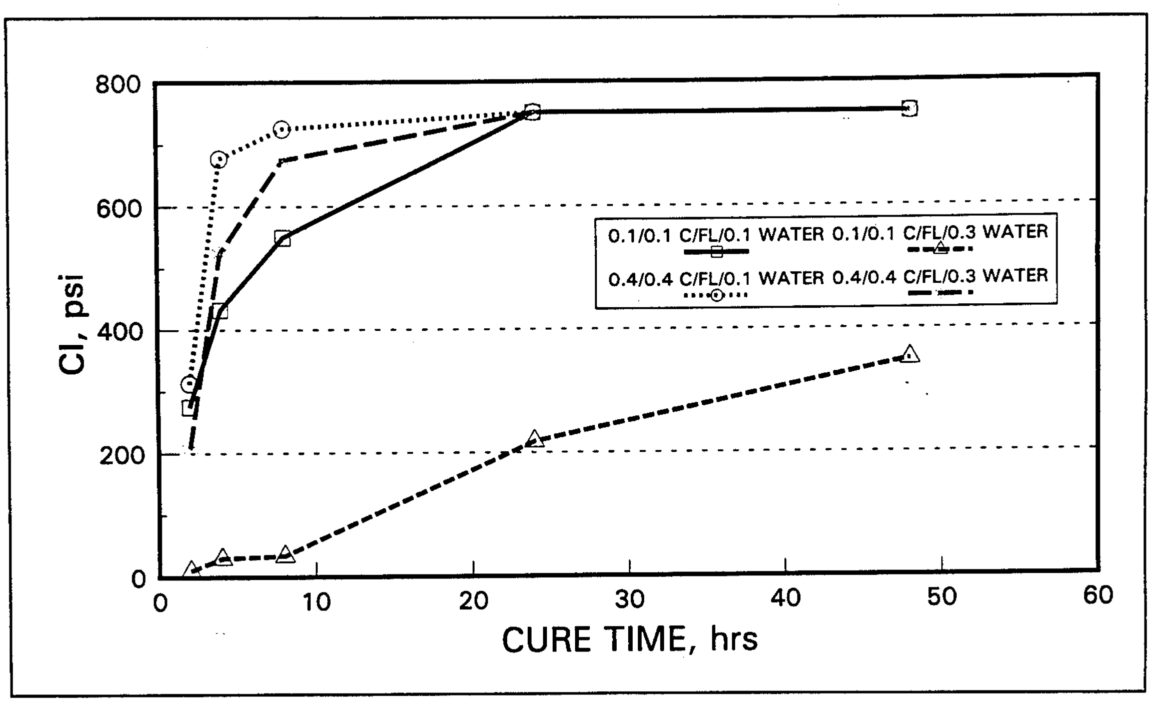

Figure 8. Average IST CI results for Soil 15 for cement/fly ash BSRs

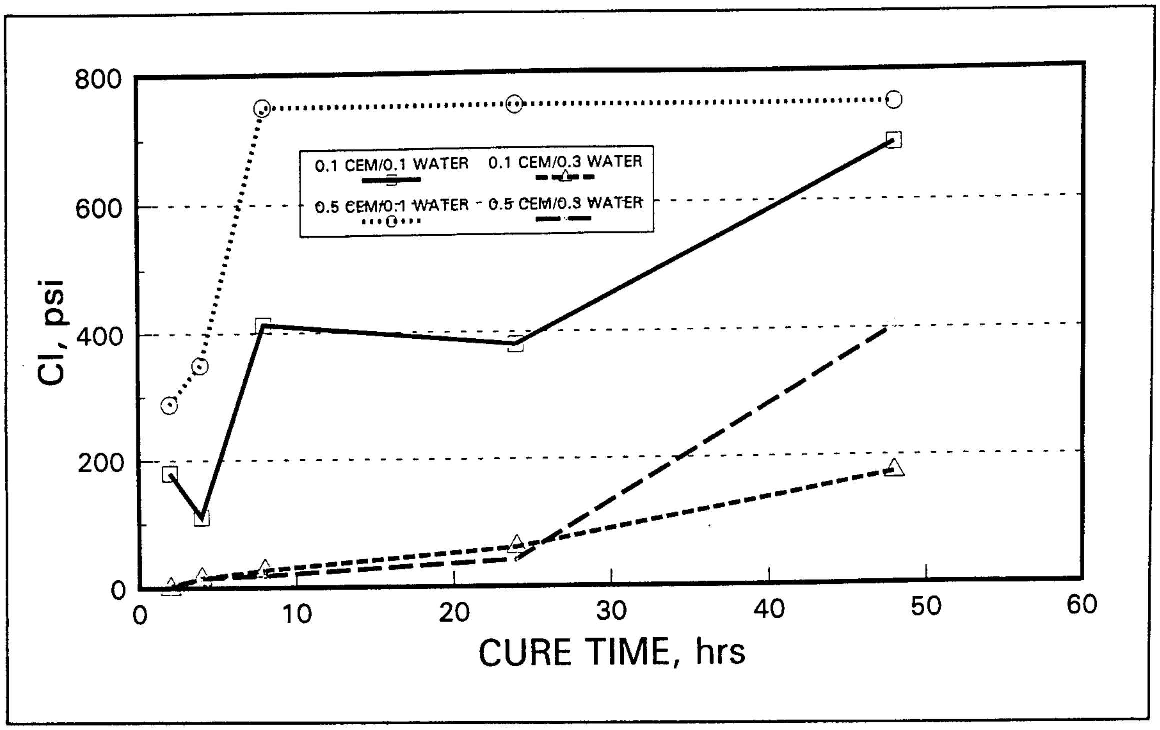

Figure 9. Average IST CI results for Soil 19 for cement BSRs

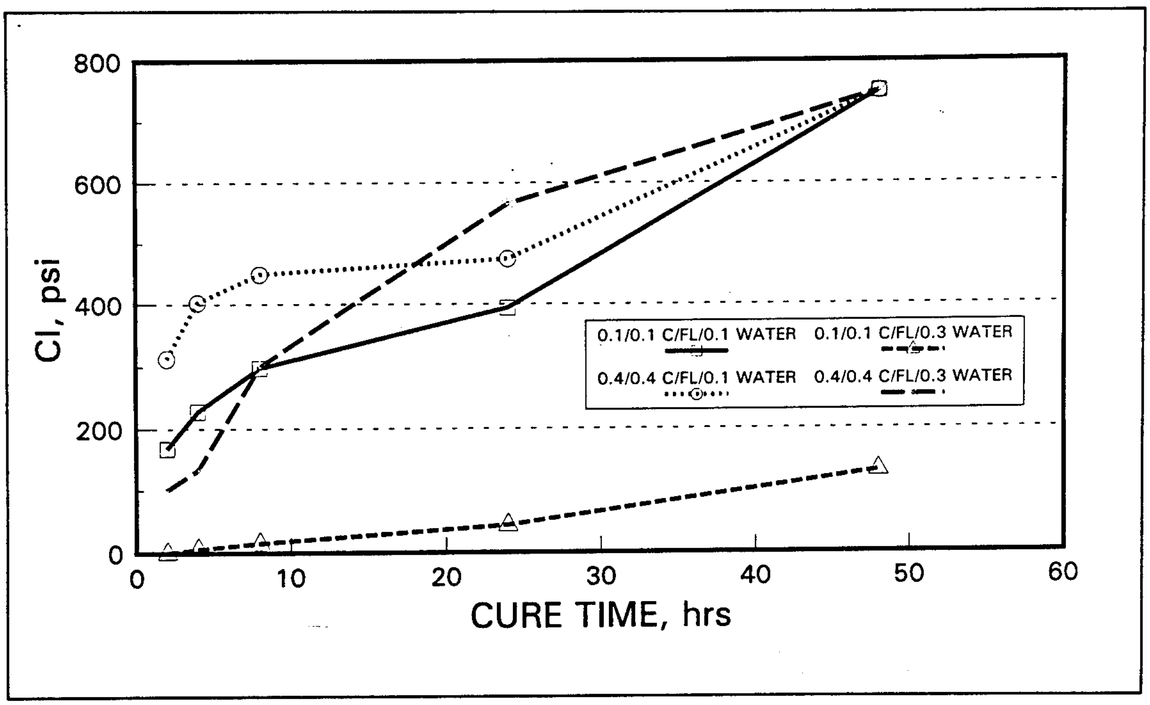

Figure 10. Average IST CI results for Soil 19 for cement/fly ash BSRs

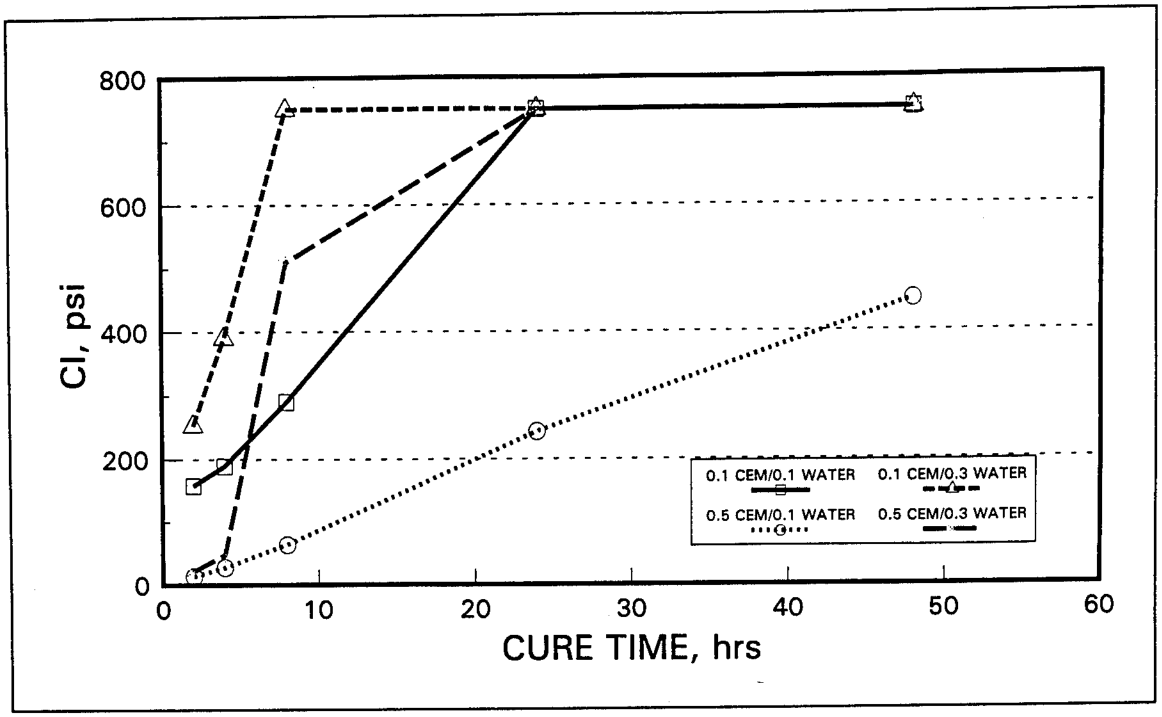

Figure 11. Average IST CI results for Soil 31 for cement BSRs

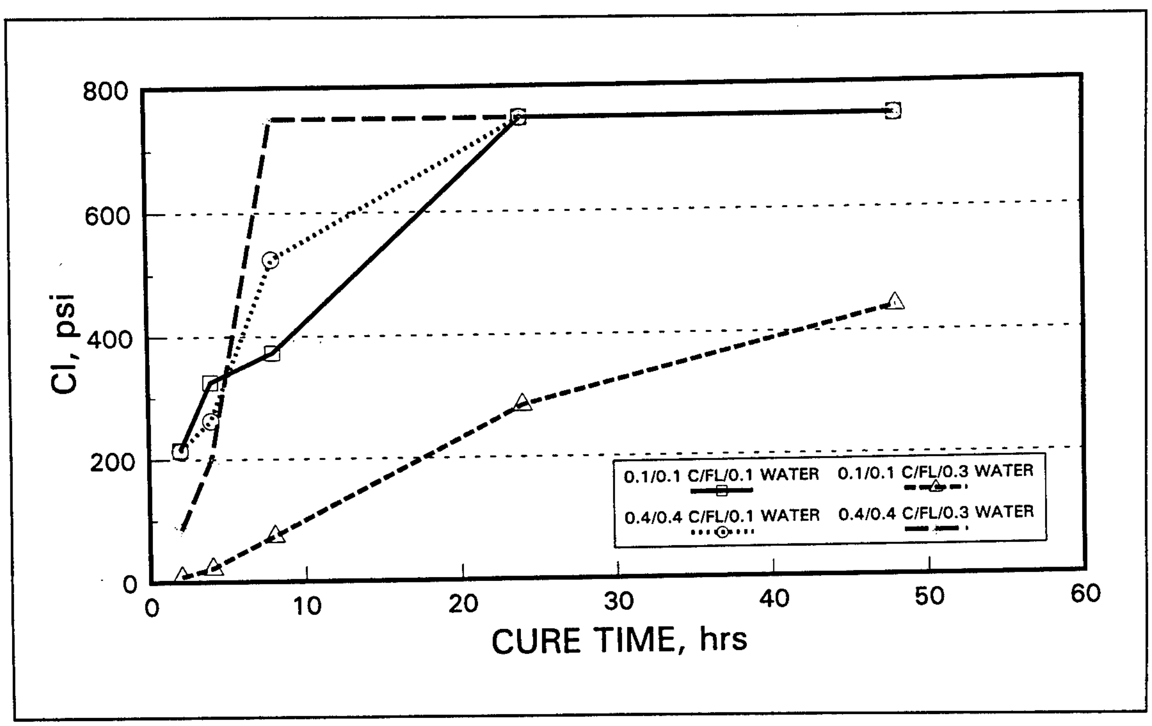

Figure 12. Average IST CI results for Soil 31 for cement/fly ash BSRs

of the sample for the 2- and 4-hr test times. The free liquid on the top of the sample had dissipated by the 8-hr cure time.

Figure 7 presents the IST CI for Soil 15 using varying cement BSRs and varying WSRs. All of the samples achieved the maximum CI of 750 psi after 24 hr of cure except for the 0.1 cement/0.3 water sample. Like the sample for Soil 2236, this sample for Soil 15 also was very wet and had free liquid on the top of the sample. The free liquid had dissipated at the 8-hr cure time.

Figure 8 presents the IST CI for Soil 15 using varying cement/fly ash BSRs with varying WSRs. All of the samples except for the 0.1 cement/0.1 fly ash/0.3 water achieved the maximum CI of 750 psi after 24 hr of cure. The 0.1 cement/0.1 fly ash/0.3 water sample was visually wet and had free liquid on the top of the sample. The free liquid had dissipated by the 8-hr cure time of the CI test.

Figure 9 presents the IST CI data for Soil 19 using varying cement BSRs and varying WSRs. Only one BSR/WSR, 0.5 cement/0.1 water, achieved the maximum CI of 750 psi. The sample prepared using the 0.1 cement BSR/ 0.1 WSR achieved a CI of 688 psi. The remaining two samples using the 0.3 WSR did not gain as much strength during the 48-hr cure time as did the samples using the 0.1 WSR.

Figure 10 presents the IST CI data for Soil 19 using varying cement/fly ash BSRs and varying WSRs. All samples evaluated using the cement/fly ash BSRs achieved the maximum CI of 750 psi except for the sample prepared using the 0.1 cement/0.1 fly ash/0.3 water. This BSR/WSR appeared to be wet when mixing and only achieved a CI of 130 psi during the 48-hr cure time.

Figure 11 presents IST CI data for Soil 31 using varying cement BSRs and varying WSRs. All of the samples prepared achieved the maximum CI of 750 psi after 48 hr of cure except for the 0.5 cement BSR/0.1 water WSR. This sample achieved a CI of 440 psi after 48 hr of cure. This sample was dry and crumbled when subjected to the CI test.

Figure 12 presents the CI data for Soil 31 using varying cement/fly ash BSRs and varying WSRs. All of the samples evaluated for the CI achieved the maximum CI of 750 psi except for the 0.1 cement/0.1 fly ash/0.1 water sample. This sample had a CI of 440 psi after the 48 hr of cure. This sample was observed to be wet while mixing and did not achieve the set as did the other samples tested.

The CI measurements for the IST were terminated after 48 hr of cure. Based on previous tests (Bricka, Holmes, and Cullinane 1988; Channell and Kosson 1993; and Bricka and Jones 1993), a 48-hr cure time has proven to provide a rapid but useful tool to aid in the water ratio selection and narrow the binder ratios to be investigated during the detailed evaluation portion of S/S investigations. Typically, low values for CI are indicative of samples that developed a free-liquid layer on the upper surface of the soil/binder/water

mixture after it had cured 48 hr. These samples generally do not develop significant strength and would present handling problems because of the free-liquid formation. (Materials containing free liquids are banned from landfilling under RCRA section 3004 (c)(1)).

Free-water formation generally occurs at the low binder/high water ratio mixtures. It is expected in cases where free water forms that the optimal water/binder ratio is far exceeded. Thus, excess water separates from the soil and rises to the surface of the sample as a result of the settling of the heavier solids. Free-water formation would be highly undesirable during the application of S/S processing and, thus, is generally avoided.

Chemical extractions (TCLPs) were also performed on the IST samples that had cured 48 hr. Tables 11 and 12 present the average results of the TCLP for the metals and explosives analysis, respectively. The individual replicate results of the IST TCLP is presented in Appendix B.

Table 11 shows that BSRs/WSRs evaluated for Soil 2236 passed the TCLP for chromium and lead. This was expected since the TCLPs performed on the untreated soil also passed for chromium and lead. Cadmium was found in the TCLP leachate above the TCLP limit, and above the performance criteria of 1.0 mg/ℓ in three of the BSR/WSRs evaluated in the IST. These BSR/WSRs were 0.1 cement/0.3 water, 0.1 cement/0.1 fly ash/0.1 water, and 0.1 cement/0.1 fly ash/0.3 water. These three samples all had cadmium in the TCLP leachate at greater than 3.10 mg/ℓ. The two samples prepared using the 0.3 WSR indicated during the CI test that strength development was because of the large amount of water added to the soil/binder mixture. Since these two samples did not achieve a high CI, it can be seen that the large addition of water with small additions of binder could potentially leach contaminants. The cement/fly ash sample using the 0.1 WSR did achieve the maximum CI of 750 psi during the 48-hr cure but still leached cadmium from the sample. All other BSR/WSRs tested passed the TCLP for cadmium.

All of the metals analyzed for Soils 15, 19, and 31 passed the TCLP and the performance criteria as shown in Table 11.

Table 12 presents the results of the TCLP of explosive compounds of the IST samples. Soil 2236 and Soil 31 did not leach any explosive compounds during the TCLP test. The TCLP leachate for Soil 15 contained appreciable levels of explosive compounds as indicated in Table 12. HMX, RDX, TNB, TNT, 4A-DNT, and 2A-DNT were present in the TCLP leachate for most of the BSRs/WSRs tested. Although HMX was present in all samples tested, the concentration of HMX was well below the performance criterion of 35.0 mg/ℓ for the study. Only one sample, 0.1 cement/0.3 water, had an RDX concentration below the performance criterion of 0.070 mg/ℓ. All remaining samples were well above the RDX performance goal. All samples tested for Soil 15 passed the performance goal of 1.80 mg/ℓ for TNB. Two samples passed the performance goal of 0.280 mg/ℓ for TNT for the TCLP. These two samples

Table 11
Average TCLP Results of Metals for IST

BSR/WSR	mg/ℓ								
	As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
Soil 2236									
Cement									
0.1/0.1	NA[1]	NA	NA	<0.01	NA	0.442	<0.01	NA	NA
0.1/0.3	NA	NA	NA	3.48	NA	<0.05	<0.01	NA	NA
0.5/0.1	NA	NA	NA	<0.01	NA	0.196	<0.01	NA	NA
0.5/0.1	NA	NA	NA	<0.01	NA	0.187	<0.01	NA	NA
Cement/Fly Ash									
0.1/0.1/0.1	NA	NA	NA	3.52	NA	<0.05	<0.01	NA	NA
0.1/0.1/0.3	NA	NA	NA	3.10	NA	0.135	<0.01	NA	NA
0.4/0.4/0.1	NA	NA	NA	<0.01	NA	0.250	<0.01	NA	NA
0.4/0.4/0.3	NA	NA	NA	<0.01	NA	2.257	<0.01	NA	NA
Soil 15									
Cement									
0.1/0.1	<0.02	4.96	<0.01	0.345	<0.05	<0.05	1.07	<0.1	<0.003
0.1/0.3	<0.02	3.28	<0.01	0.306	<0.05	<0.05	0.187	<0.1	<0.003
0.5/0.1	<0.02	1.53	<0.01	<0.01	<0.05	0.118	<0.01	<0.1	<0.003
0.5/0.3	<0.02	2.54	<0.01	<0.01	<0.05	0.215	<0.01	<0.1	<0.003
Cement/Fly Ash									
0.1/0.1/0.1	<0.02	1.21	<0.01	<0.01	<0.05	0.198	<0.01	<0.1	<0.003
0.1/0.1/0.3	<0.02	1.83	<0.01	<0.01	<0.05	0.124	<0.01	<0.1	<0.003
0.4/0.4/0.1	<0.02	1.58	<0.01	<0.01	<0.05	0.178	<0.01	<0.1	<0.003
0.4/0.4/0.3	<0.02	3.09	<0.01	0.261	<0.05	0.062	0.227	<0.1	<0.003
Soil 19									
Cement									
0.1/0.1	<0.02	1.97	NA	<0.01	NA	<0.05	<0.1	0.149	NA
0.1/0.3	<0.02	2.25	NA	0.096	NA	<0.05	0.165	0.168	NA
0.5/0.1	<0.02	1.92	NA	<0.01	NA	<0.05	0.377	<0.1	NA
0.5/0.3	<0.02	2.73	NA	<0.01	NA	<0.05	0.928	<0.1	NA

(Continued)

Note: Shaded area denotes sample failed to meet performance criteria for the study.
[1] Not analyzed.

Table 11 (Concluded)									
	mg/ℓ								
BSR/WSR	As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
Soil 19									
Cement/Fly Ash									
0.1/0.1/0.1	<0.02	3.98	NA	0.226	NA	<0.05	0.311	0.183	NA
0.1/0.1/0.3	<0.02	2.33	NA	<0.01	NA	<0.05	<0.1	0.141	NA
0.4/0.4/0.1	<0.02	2.64	NA	<0.01	NA	<0.05	1.31	<0.1	NA
0.4/0.4/0.3	<0.02	2.70	NA	<0.01	NA	<0.05	1.86	<0.1	NA
Soil 31									
Cement									
0.1/0.1	NA	NA	NA	<0.01	NA	<0.05	<0.1	NA	NA
0.1/0.3	NA	NA	NA	<0.01	NA	<0.05	<0.1	NA	NA
0.5/0.1	NA	NA	NA	<0.01	NA	0.073	<0.1	NA	NA
0.5/0.3	NA	NA	NA	<0.01	NA	0.067	<0.1	NA	NA
Cement/Fly Ash									
0.1/0.1/0.1	NA	NA	NA	<0.01	NA	<0.05	<0.1	NA	NA
0.1/0.1/0.3	NA	NA	NA	<0.01	NA	<0.05	<0.1	NA	NA
0.4/0.4/0.1	NA	NA	NA	0.13	NA	<0.05	<0.1	NA	NA
0.4/0.4/0.3	NA	NA	NA	<0.01	NA	<0.05	<0.1	NA	NA

were 0.1 cement/0.3 water and 0.4/0.4 cement/fly ash/0.1 water. All remaining samples for Soil 15 failed to meet the performance goal for TNT. Samples prepared for Soil 19 showed concentrations of RDX, HMX, TNB, and TNT in the TCLP leachate. All samples were below the performance goals for HMX and TNB for this study. Four samples failed to meet the performance goals for RDX and TNT. These four samples were 0.1 cement/0.1 water, 0.1 cement 0.3 water, 0.1/0.1 cement/fly ash/0.1 water, and 0.1/0.1 cement/fly ash/ 0.3 water. All other samples for Soil 19 were below the detection limit for RDX and TNT.

Both the CI and TCLP results for the IST were considered in making a determination of the WSRs and the range of BSRs to be used in the detailed evaluation portion of this study. In making this selection for the ratios to be considered for further evaluation, the criteria listed below are generally followed.

Table 12
Average TCLP Results of Explosive Compounds for IST

BSR/WSR	HMX	RDX	TNB	DNB	Tetryl	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT
	mg/ℓ									
Soil 2236										
Cement										
0.1/0.1	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.1/0.3	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.5/0.1	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.5/0.3	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
Cement/Fly Ash										
0.1/0.1/0.1	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.1/0.1/0.3	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.4/0.4/0.1	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.4/0.4/0.3	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
Soil 15										
Cement										
0.1/0.1	1.68	1.88	0.058	<0.02	<0.05	0.358	0.481	0.044	<0.02	<0.02
0.1/0.3	1.15	0.031	0.016	<0.02	<0.05	<0.02	<0.02	0.024	<0.02	<0.02
0.5/0.1	3.08	12.08	0.066	<0.02	<0.05	2.24	2.24	0.063	<0.02	<0.02
0.5/0.3	2.14	3.58	0.081	<0.02	<0.05	1.47	1.47	0.042	<0.02	<0.02

(Sheet 1 of 3)

Note: Shaded area denotes that sample failed to meet performance criteria for study.

Table 12 (Continued)

BSR/WSR	mg/ℓ									
	HMX	RDX	TNB	DNB	Tetryl	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT
Soil 15										
Cement/Fly Ash										
0.1/0.1/0.1	1.89	1.92	0.065	<0.02	<0.05	0.329	0.042	0.023	<0.02	<0.02
0.1/0.1/0.3	1.55	3.04	0.112	<0.02	<0.05	0.884	0.884	<0.02	<0.02	<0.02
0.4/0.4/0.1	0.797	0.875	0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.4/0.4/0.3	0.689	1.94	0.033	<0.02	<0.05	0.278	0.278	<0.02	<0.02	<0.02
Soil 19										
Cement										
0.1/0.1	0.243	0.243	0.179	<0.02	<0.05	5.21	<0.02	<0.02	<0.02	<0.02
0.1/0.3	0.159	0.113	0.135	<0.02	<0.05	2.88	<0.02	<0.02	<0.02	<0.02
0.5/0.1	0.119	<0.02	0.008	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.5/0.3	0.067	<0.02	0.014	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
Cement/Fly Ash										
0.1/0.1/0.1	1.11	7.69	0.194	<0.02	<0.05	4.42	<0.02	<0.02	<0.02	<0.02
0.1/0.1/0.3	0.137	0.105	0.222	<0.02	<0.05	1.43	<0.02	<0.02	<0.02	<0.02
0.4/0.4/0.1	0.167	<0.02	0.052	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.4/0.4/0.3	0.079	<0.02	0.016	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02

(Sheet 2 of 3)

Table 12 (Concluded)

BSR/WSR	mg/ℓ									
	HMX	RDX	TNB	DNB	Tetryl	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT
Soil 31										
Cement										
0.1/0.1	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.1/0.3	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.5/0.1	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.5/0.3	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
Cement/Fly Ash										
0.1/0.1/0.1	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.1/0.1/0.3	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.4/0.4/0.1	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.4/0.4/0.3	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02

(Sheet 3 of 3)

a. Ratios that exhibit free-liquid formation are avoided.

b. Forty-eight-hour CI test results are maximized.

c. Concentration of TCLP analytes are minimized.

d. Attempts are made to select the minimum binder ratios that develop high 48-hr strength but have minimum TCLP leachate concentrations.

Based on the results of the IST for the cement binders, BSRs of 0.1, 0.3, 0.5, and 0.7 and a WSR of 0.2 were chosen for all soils for further evaluation. Cement/fly ash BSRs of 0.1/0.1, 0.1/0.3, 0.3/0.1, and 0.3/0.3 and a WSR of 0.2 were chosen for all soils for further evaluation during this study.

Detailed Evaluation

Based on the results of the IST, four cement binder and four cement/fly ash binder formulations were chosen for the detailed evaluation. One WSR ratio of 0.2 was chosen for all samples evaluated during the detailed evaluation portion of this study. Results of the detailed evaluation are presented in Appendix C and discussed below.

A combination of eight tests were utilized to measure the physical properties of the CSS soils in the detailed evaluation portion of this study. These tests included bulk density, bleed water, cracking, UCS, CI, workability (slump), specific gravity, and paint filter. The replicate data generated from these tests are presented in Appendix C, and the average results for each test are discussed below.

Bulk density

The average results of the bulk density tests are presented in Figures 13-16. The bulk density for Soils 2236, 19, and 31 indicate that as the cement and cement/fly ash BSR increases, the bulk density increases for the samples evaluated. It is expected that as more binder material is added to the sample, the bulk density of the sample will increase. Figure 14 shows that for Soil 15 the maximum bulk density is achieved with the 0.3 and 0.5 cement BSR and the 0.3/0.1 cement/fly ash BSR.

Based on the bulk density of the treated soil and the Proctor density of the untreated soil, the volumetric change caused by the addition of binders was calculated using Equations 1-3, as described in the Methods and Materials section of this report.

Figures 17-20 present the percent volumetric change of the solidified samples as compared with the untreated soil. All BSRs evaluated for the four soils

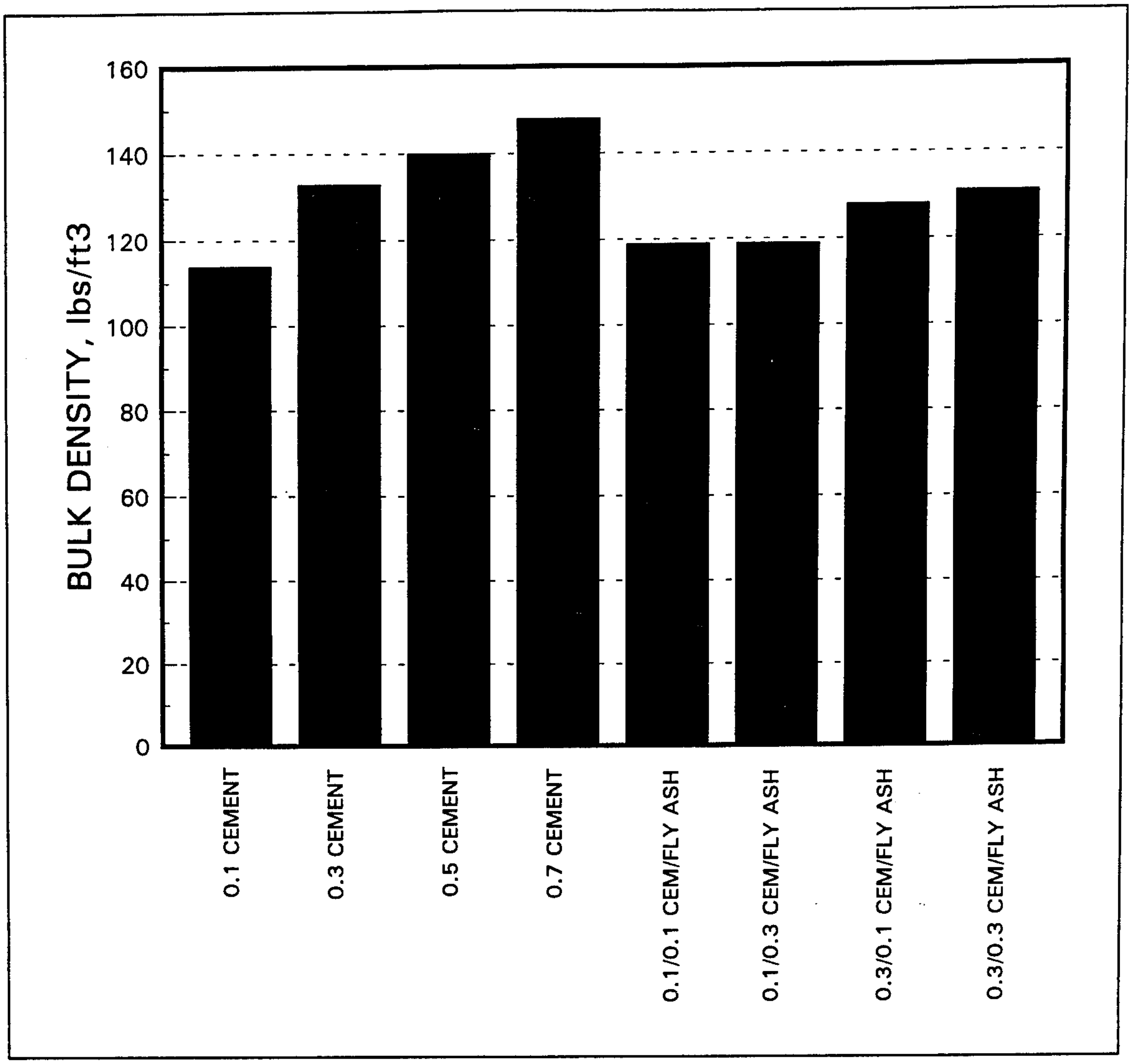

Figure 13. Average bulk density of Soil 2236 for all BSRs

showed the same trend for volume increase. The percent volume increase for the cement increases as the BSR increases. The percent volume increase for the cement/fly ash samples also increases as the BSR increases. The addition of fly ash to the samples appears to affect the volume increase more than the addition of the cement; thus, the 0.3 fly ash BSR samples had higher percent volume increase than did the 0.1 fly ash BSR samples.

Paint filter and bleed water

The paint filter test was performed immediately after the mixing process was completed. Water was observed to pass through the paint filter for the 0.1 and 0.3 cement BSRs and the 0.1/0.1 cement/fly ash BSR for all soils evaluated. The presence of free liquids formed from the mixtures indicates

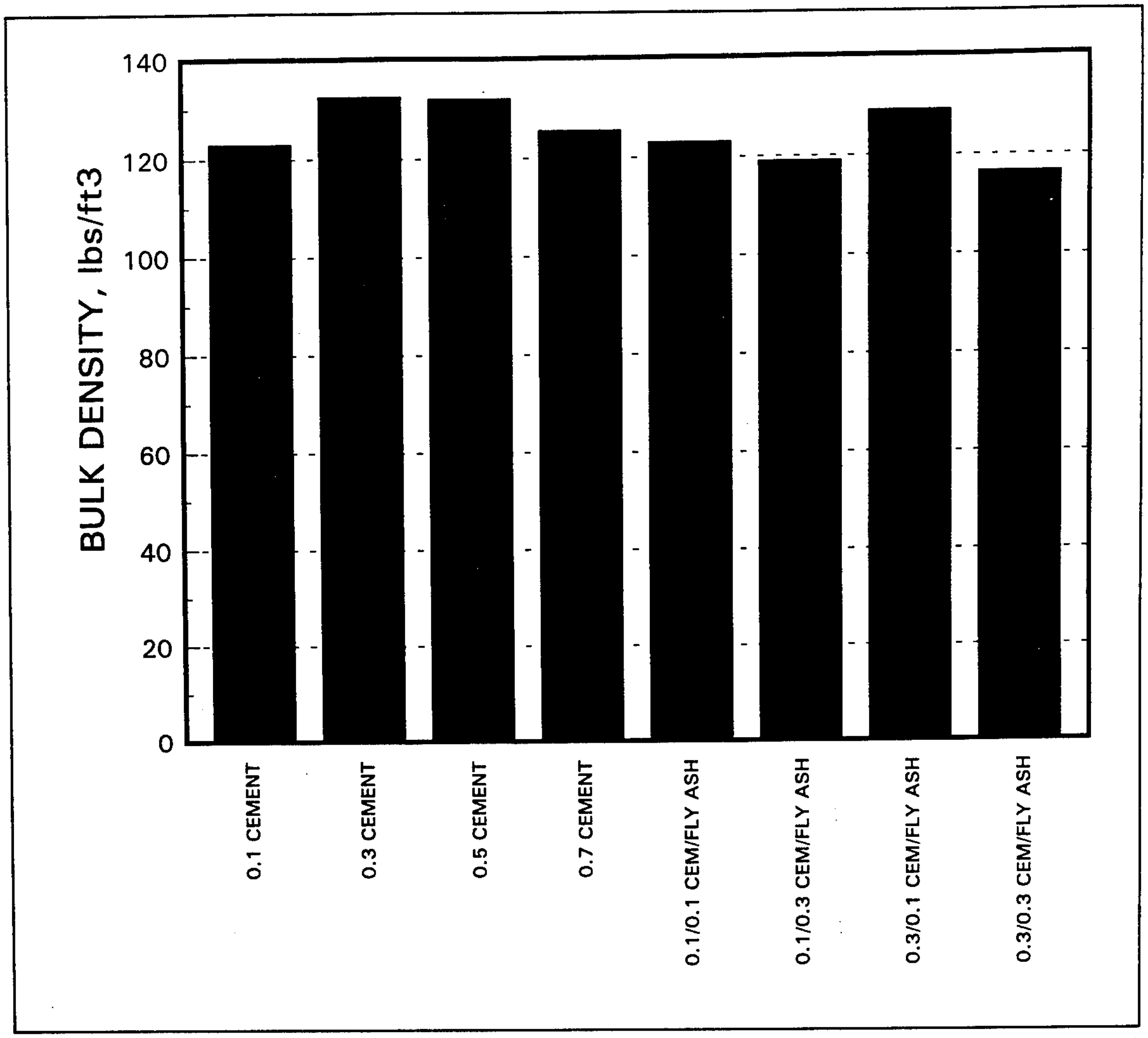

Figure 14. Average bulk density of Soil 15 for all BSRs

that the binder materials did not hydrate all of the water during the mixing process. No water was observed to pass through the paint filter for any of the remaining BSR tests in the detailed evaluation.

Even though the 0.1, 0.3 cement BSRs and 0.1/0.1 cement/fly ash BSR produced free liquid during the paint filter test, there were no free liquids (bleed water) observed on any of the samples after 48 hr of cure. A small amount of bleed water was observed on the samples that failed the paint filter test, but this water appeared to dissipate as the cure time increased for the samples. Usually if bleed water is observed on the surface of the samples, the testing of the samples is terminated at that point. Since the bleed water dissipated within 48 hr of cure, the testing of the BSRs with bleed water was continued throughout the detailed evaluation portion of this study.

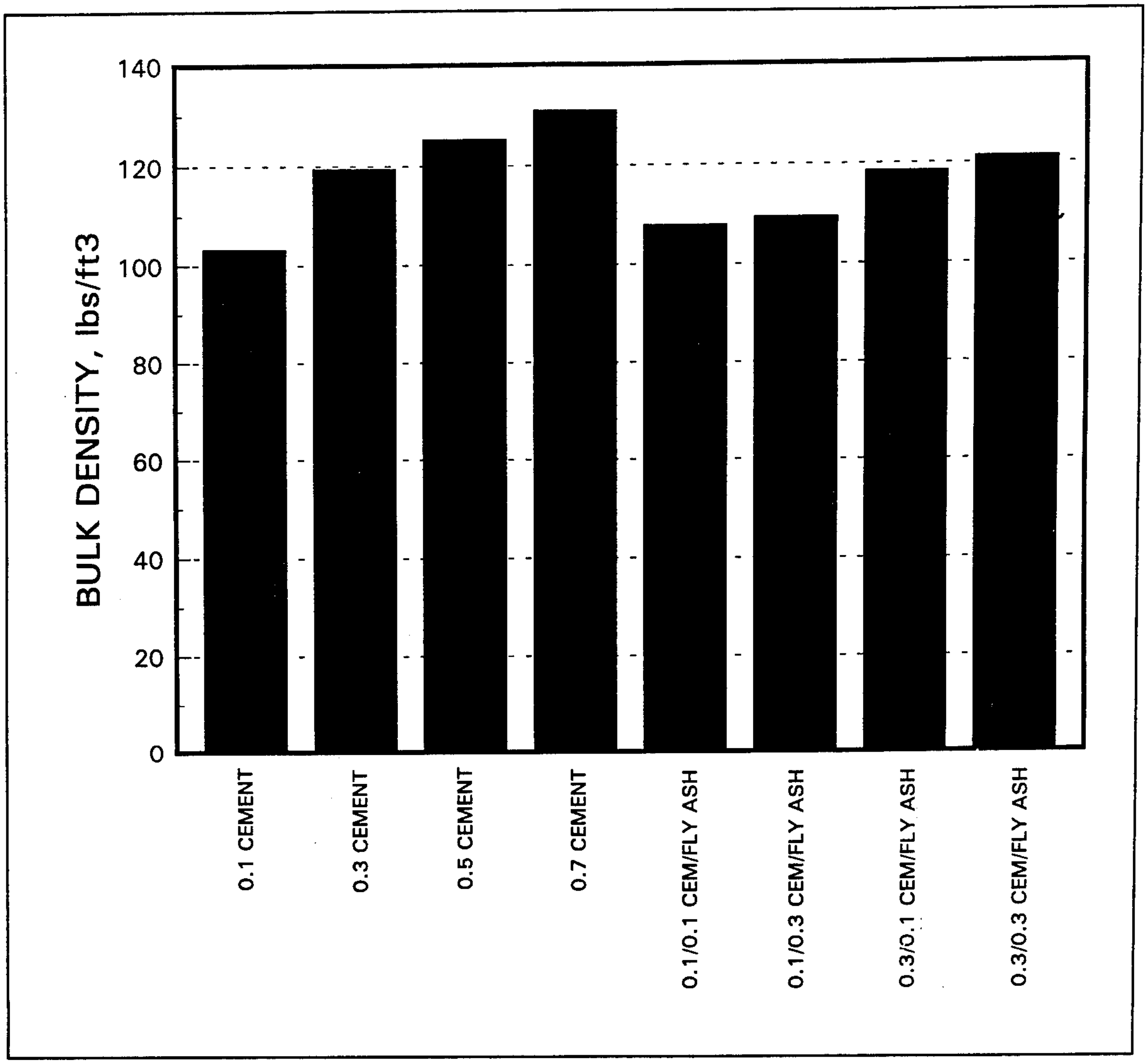

Figure 15. Average bulk density of Soil 19 for all BSRs

Workability (slump)

Results of the slump test are presented in Appendix C. The slump test was performed only on Replicate A for all binders tested. The cement BSRs of 0.1 and 0.3 all had the maximum slump of 12 in. This indicates that the mixtures were flowable and had no cohesive properties to allow the mixture to stand during the test. The 0.5 cement BSR had an average slump of 1 in. for all soils except Soil 2236, which had a slump of 4 3/8 in. The 0.7 cement BSR had an average slump of 1/8 in. for all soils tested. This slump for the cement BSRs indicates that as more binder material is added to the soil/water mixture, the slump decreases and the sample becomes more cohesive.

The slump test for the cement/fly ash BSRs shows that all samples prepared for the four soils using the 0.1 cement/0.1 fly ash BSR had a slump of 12 in.

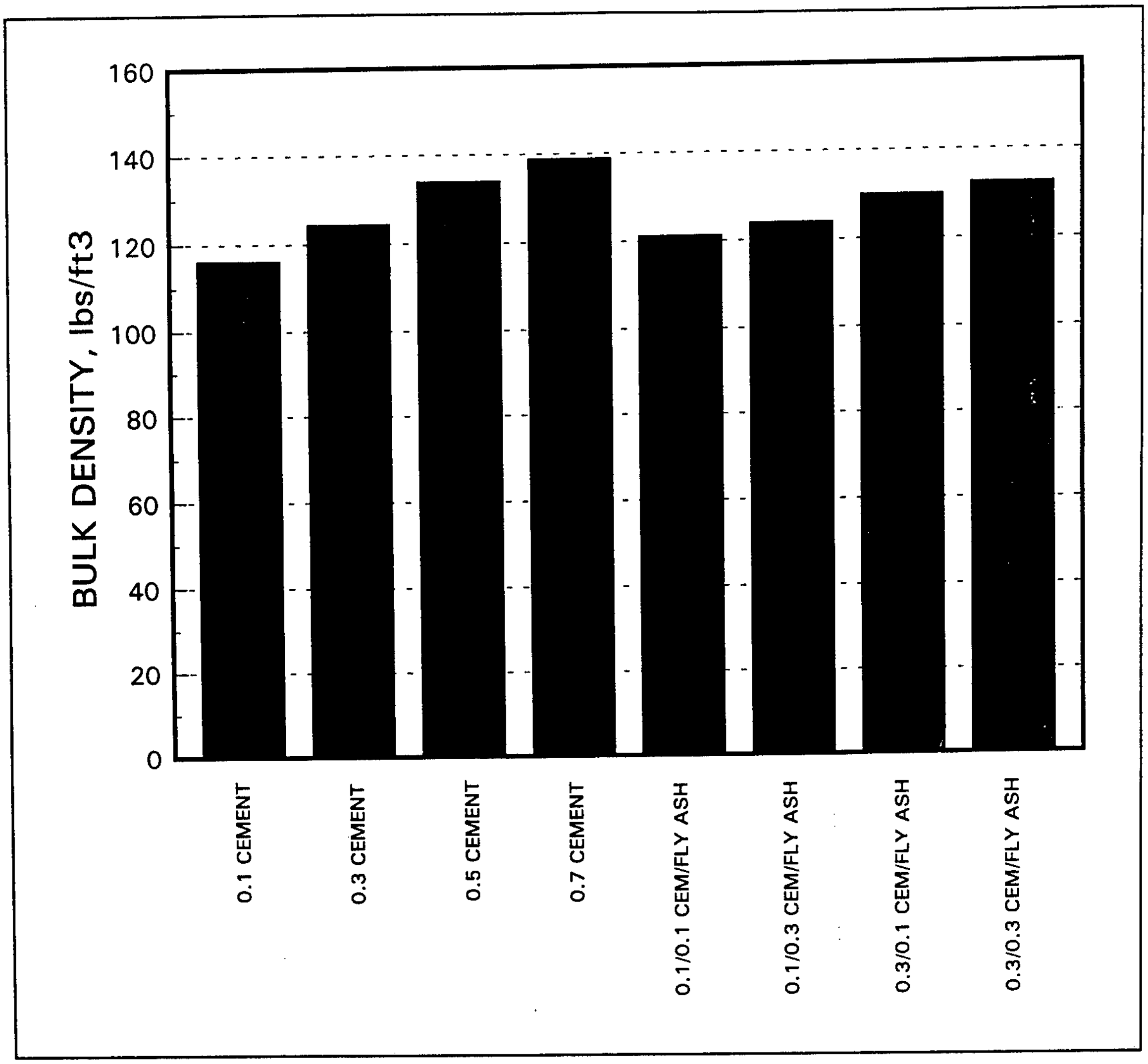

Figure 16. Average bulk density of Soil 31 for all BSRs

This mixture, like the 0.1 and 0.3 cement BSRs, was flowable and had no cohesive properties to allow it to stand during the test. As the cement/fly ash BSR is increased, the slump decreased for all samples prepared for the four soils. The 0.1/0.3 BSR had an average slump of 1 1/2 in. for all soils tested. The 0.3/0.1 BSR had an average slump of 4 in. for all soils tested and the 0.3/0.3 BSR had an average slump of 1/4 in. for all soils tested. From these results, it is observed that as cement and fly ash are increased in the sample, the slump decreases.

Cracking

All of the specimens prepared were visually inspected for cracking as described in the Methods and Materials section of this report. All of the samples prepared for all four soils were free from visual cracks. The development

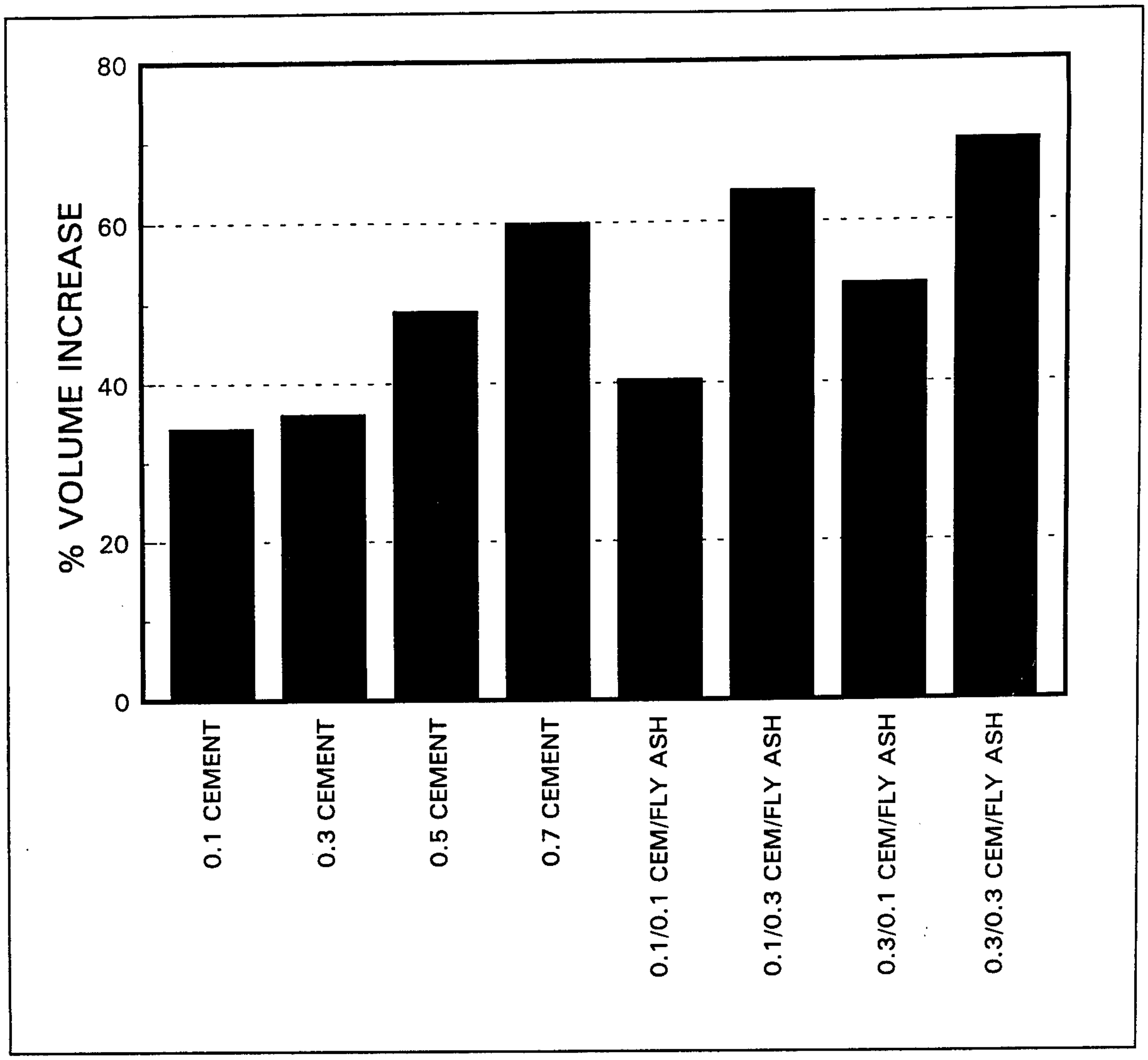

Figure 17. Average volume increase of BSRs for Soil 2236

of a large number of cracks could be an indication of soil incompatibility with the binder material.

Cone Index

Results of the CI data for the detailed evaluation are presented in Appendix C. The average results of the CI for each BSR tested for each soil are presented in Figures 21-28. Figures 21 and 22 present the average CI data for the cement and cement/fly ash BSRs for Soil 2236. These two figures show that all samples achieved the maximum CI of 750 psi after 48 hr of cure except for the 0.1 cement and 0.1/0.1 cement/fly ash BSRs. Figures 21 and 22 show that as the BSR is increased for both the cement and cement/fly ash BSRs for Soil 2236, the samples set faster and reach the maximum 750 psi.

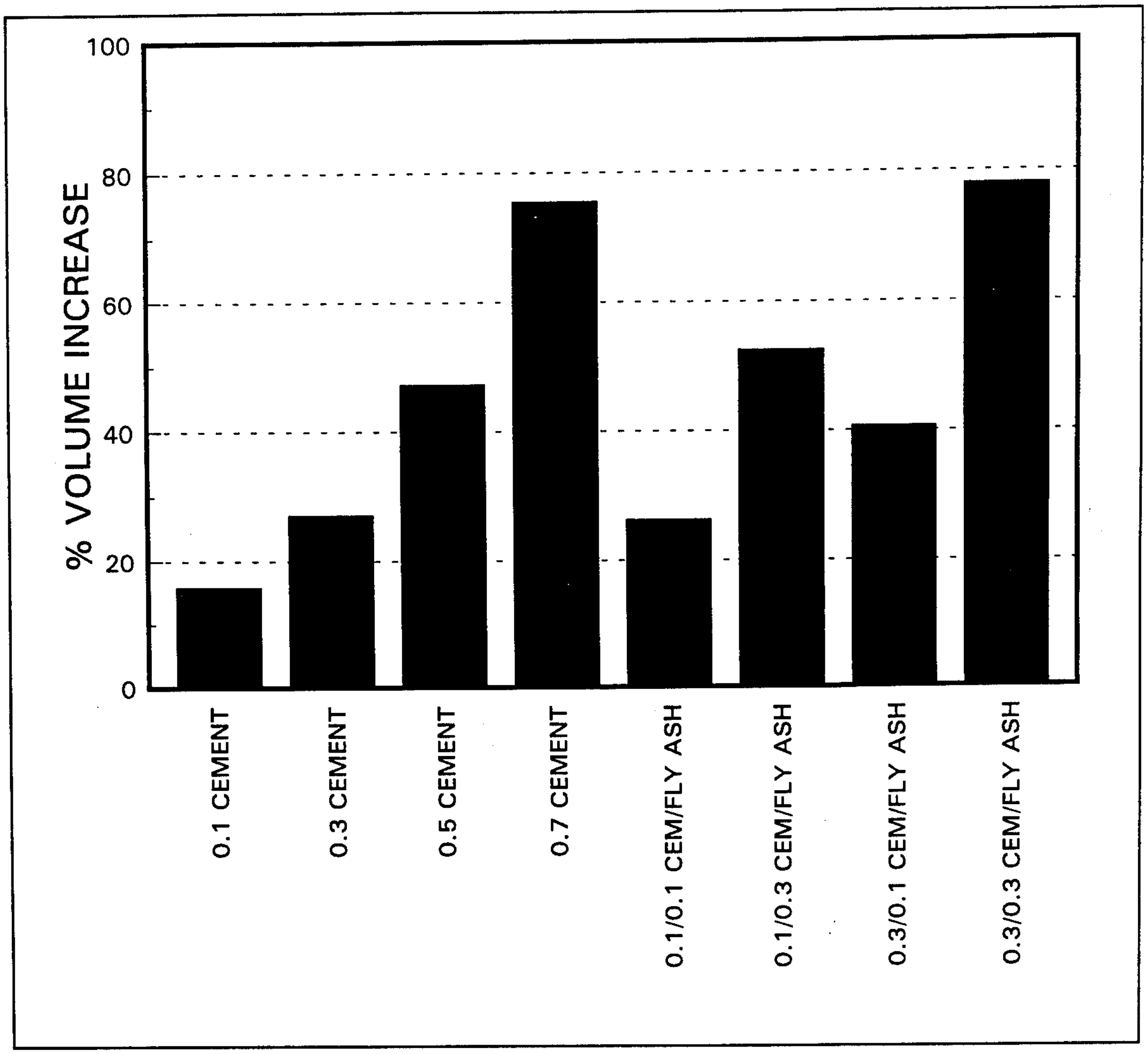

Figure 18. Average volume increase of BSRs for Soil 15

Figures 23 and 24 present the average CI data for the cement and cement/fly ash BSRs for Soil 15. Figure 23 shows that for the cement BSRs evaluated, only the 0.3 cement BSR achieved the maximum CI of 750 psi after 48 hr of cure. The 0.5 and 0.7 cement BSRs had the lowest CI of the four BSRs evaluated. Table C7 in Appendix C shows that Replicate B for the 0.5 and 0.7 BSRs did not duplicate the results of Replicate A. Replicate A for both the 0.5 and 0.7 BSRs achieved the maximum CI of 750 psi after 8 hr of cure. It was noticed while performing the CI on the 0.5 and 0.7 BSRs that Replicate B had a distinct red color that was not present in Replicate A. It has been shown that the presence of organic compounds in materials that are being solidified retards the set of the solidified mixture (Bricka and Jones 1993). This could possibly be the explanation for the red color and low CI for Replicate B for the cement BSRs of 0.5 and 0.7. Figure 24 presents the CI data for the cement/fly ash BSRs for Soil 15. All samples tested achieved the maximum CI of 750 psi after 48 hr of cure except the 0.1/0.1 cement/fly ash BSR. Figure 24 shows that as the BSR is increased, the samples achieve a faster

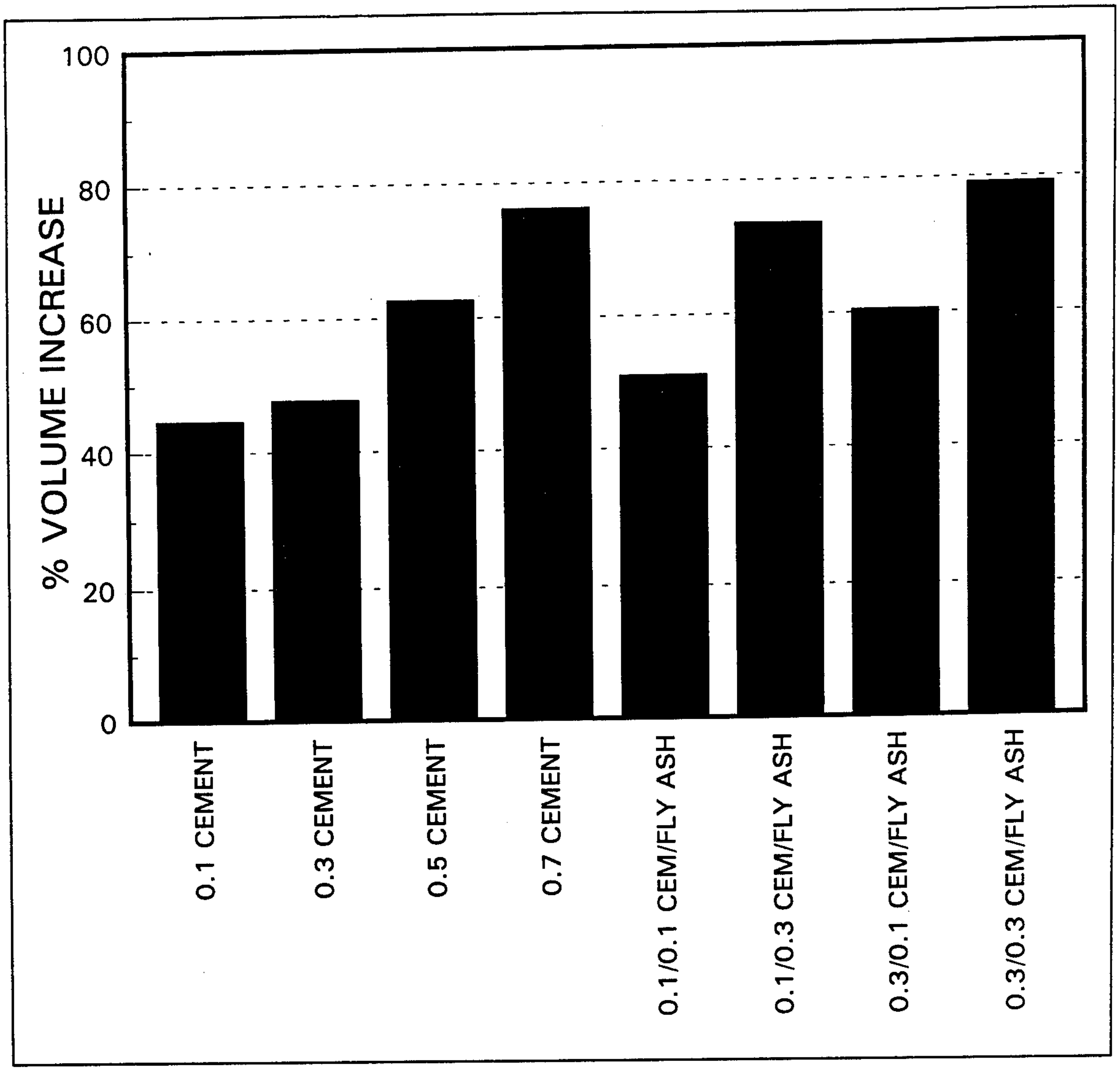

Figure 19. Average volume increase of BSRs for Soil 19

set and greater CI. It should be noted that the soil for the preparation of cement/fly ash BSRs was not taken from the same buckets used for the cement BSRs.

Figure 25 presents the CI data for the cement BSRs evaluated for Soil 19. The BSR of 0.3 cement achieved the maximum CI of 750 psi after 48 hr of cure. The 0.5 and 0.7 BSRs had the lowest CI of the four BSRs evaluated for the CI test. Like Soil 15, the Replicates for the 0.5 BSR did not duplicate each other. Replicate B achieved the maximum CI of 750 psi after 24 hr of cure while Replicate A only achieved a CI of 125 psi after 48 hr of cure. Replicates A and B for the 0.7 BSR did duplicate each other with a CI of 430 psi after 48 hr of cure. As previously discussed for Soil 15, the presence of high concentrations of organic compounds could be the cause of the low CI for the 0.5 and 0.7 BSRs evaluated for the CI test.

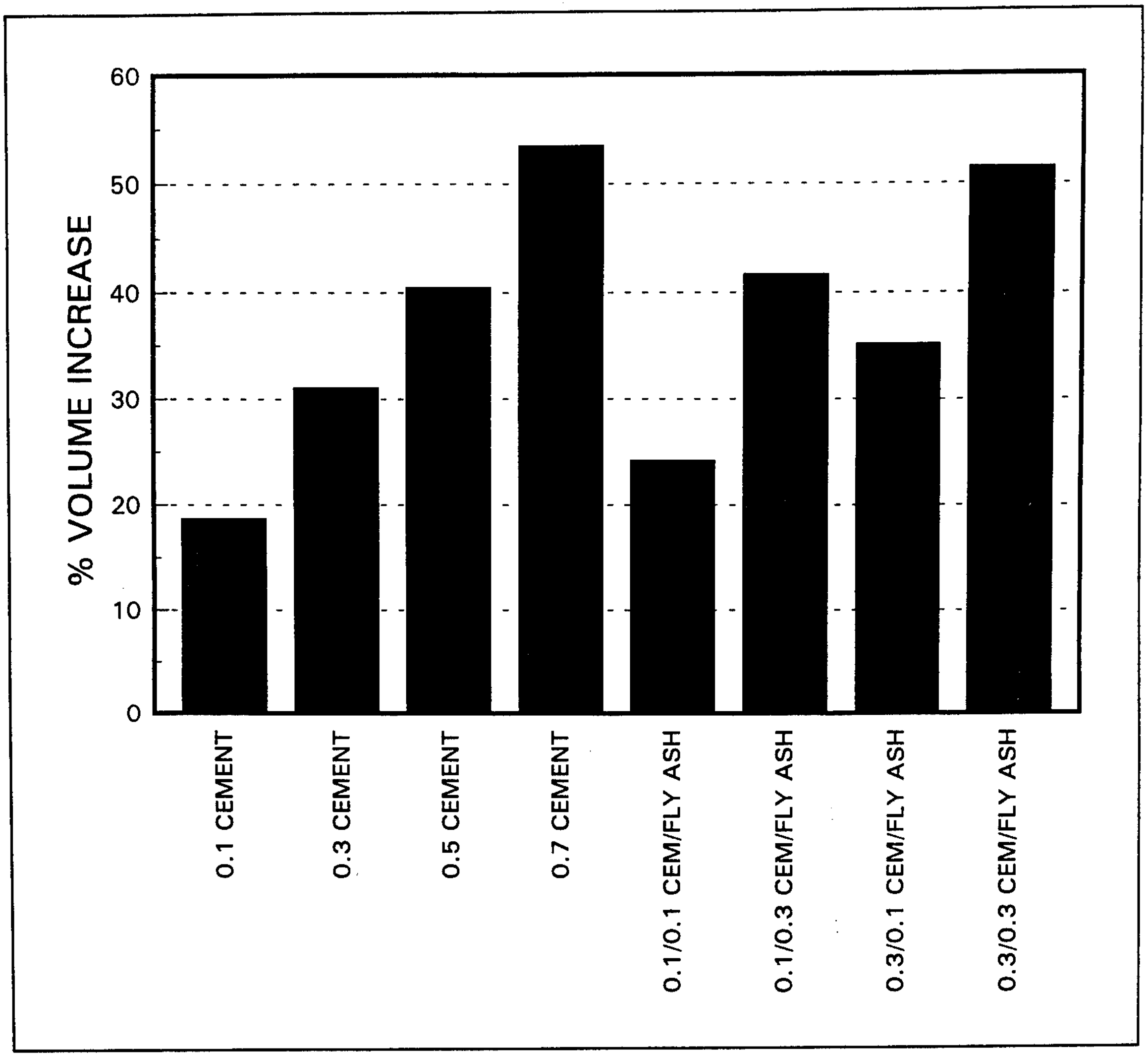

Figure 20. Average volume increase of BSRs for Soil 31

Figure 26 presents the CI results for the cement/fly ash BSRs for Soil 19. Figure 26 shows that only the BSR of 0.3/0.3 cement/fly ash achieved the maximum CI of 750 psi after 48 hr of cure. Table C7 in Appendix C shows that the replicates of 0.1/0.1, 0.1/0.3, and 0.3/0.1 cement/fly ash do not duplicate each other for the CI test. Replicate A achieved a higher CI than did Replicate B. While neither the 0.1/0.1 or 0.1/0.3 cement/fly ash samples reached 750 psi for the CI test, Replicate A for the 0.3/0.1 cement/fly ash sample did achieve the maximum CI of 750 psi. Replicate B for the 0.3/0.1 cement/fly ash sample only achieved a CI of 105 psi for the test. As previously discussed, the presence of organic contaminants in the soil could possibly interfere with the set of the sample. Although discrepancies were observed in the replicates, it can still be seen in Table C7 of Appendix C and Figure 26 that as the cement/fly ash BSR is increased, the CI for Soil 19 increases.

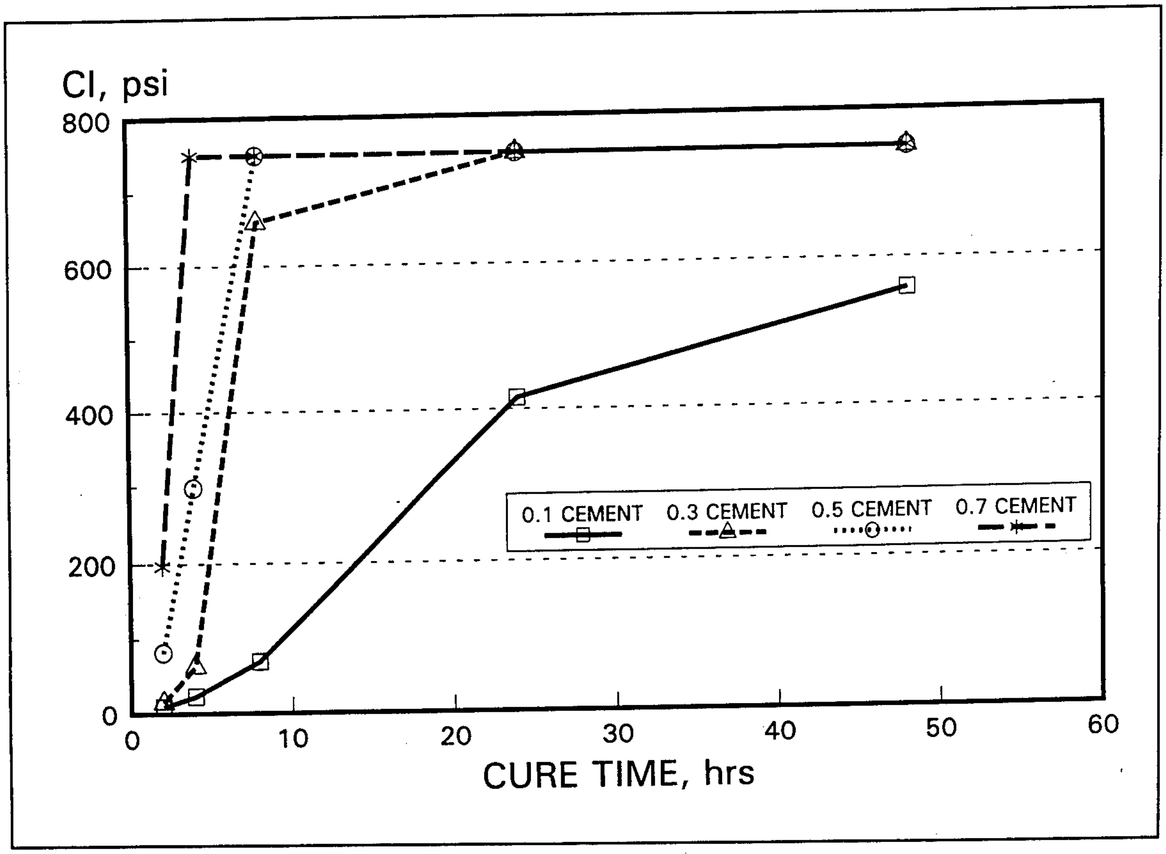

Figure 21. Average CI results for Soil 2236 for cement BSRs

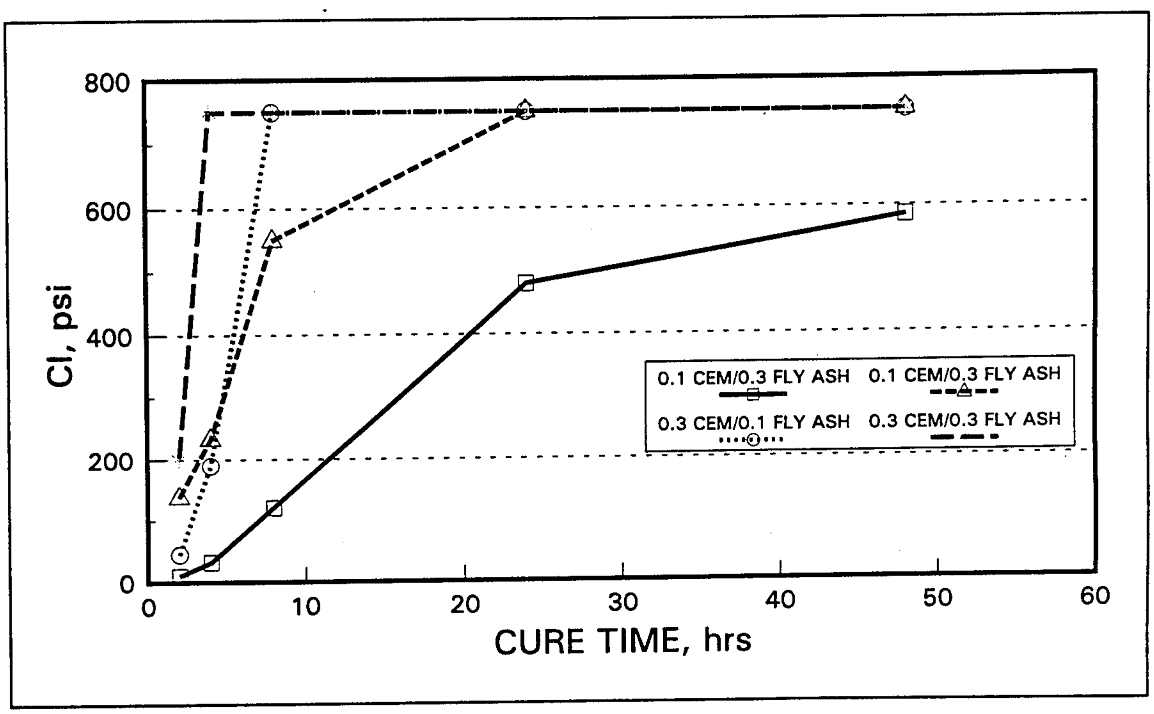

Figure 22. Average CI results for Soil 2236 for cement/fly ash BSRs

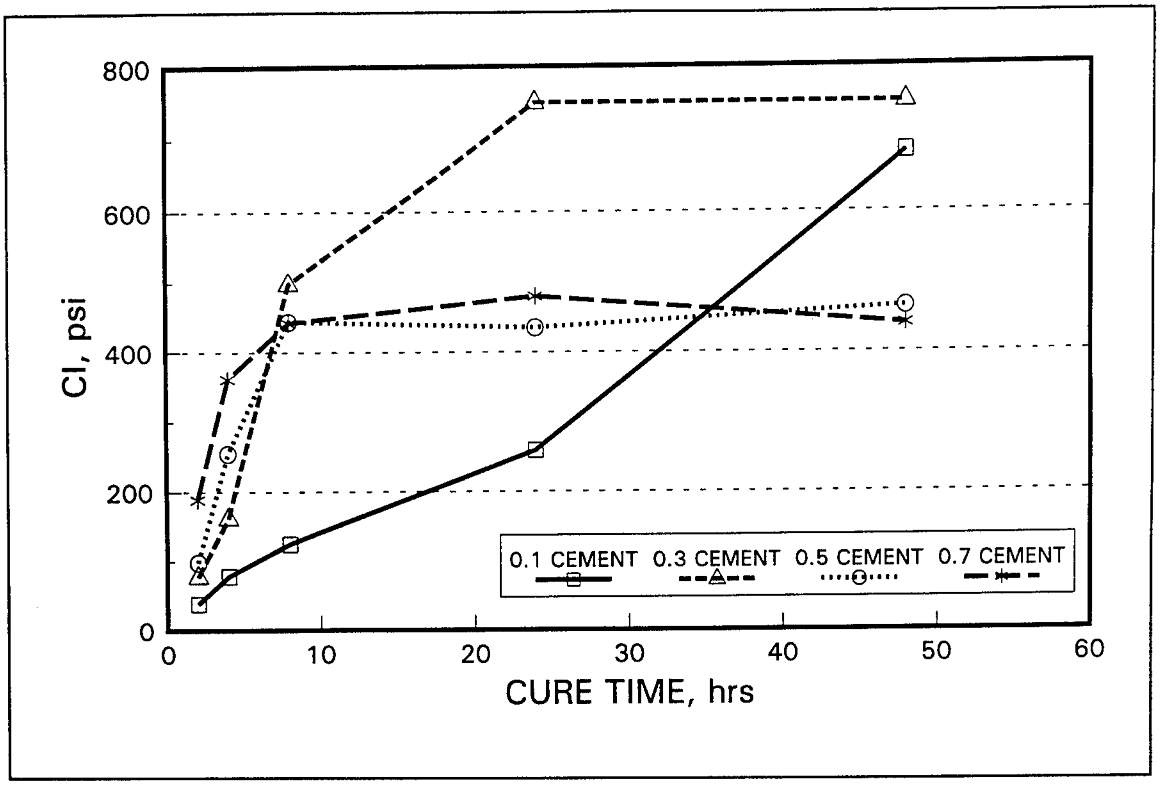

Figure 23. Average CI results for Soil 15 for cement BSRs

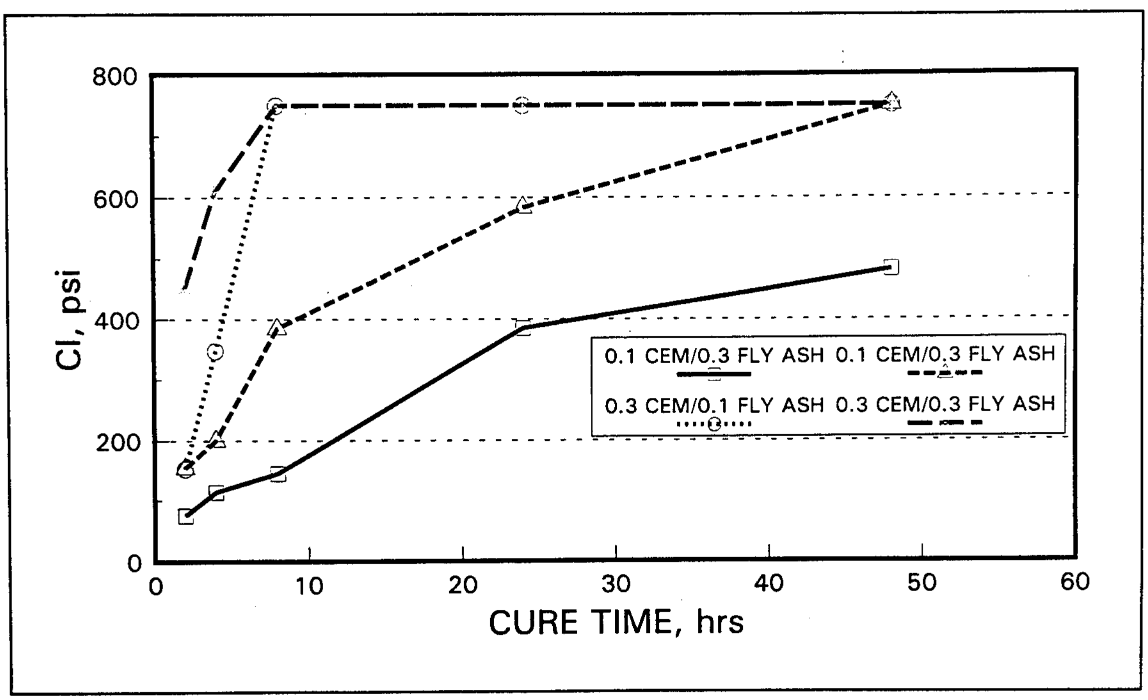

Figure 24. Average CI results for Soil 15 for cement/fly ash BSRs

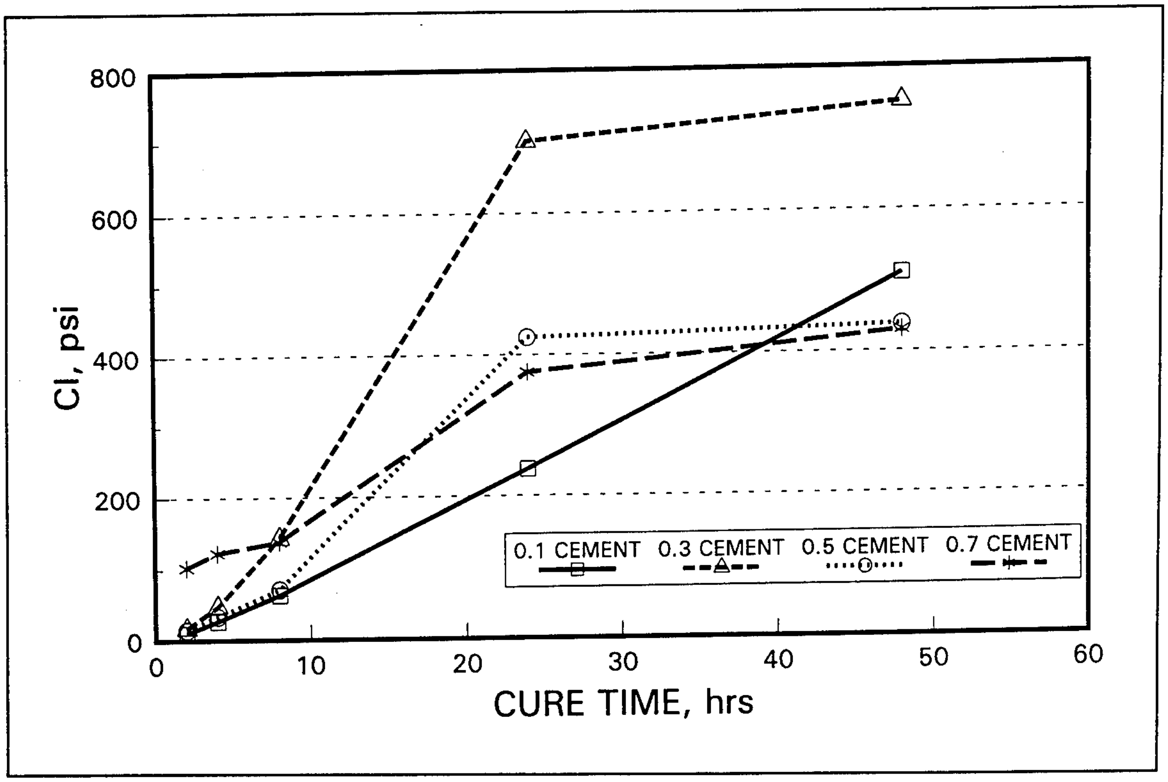

Figure 25. Average CI results for Soil 19 for cement BSRs

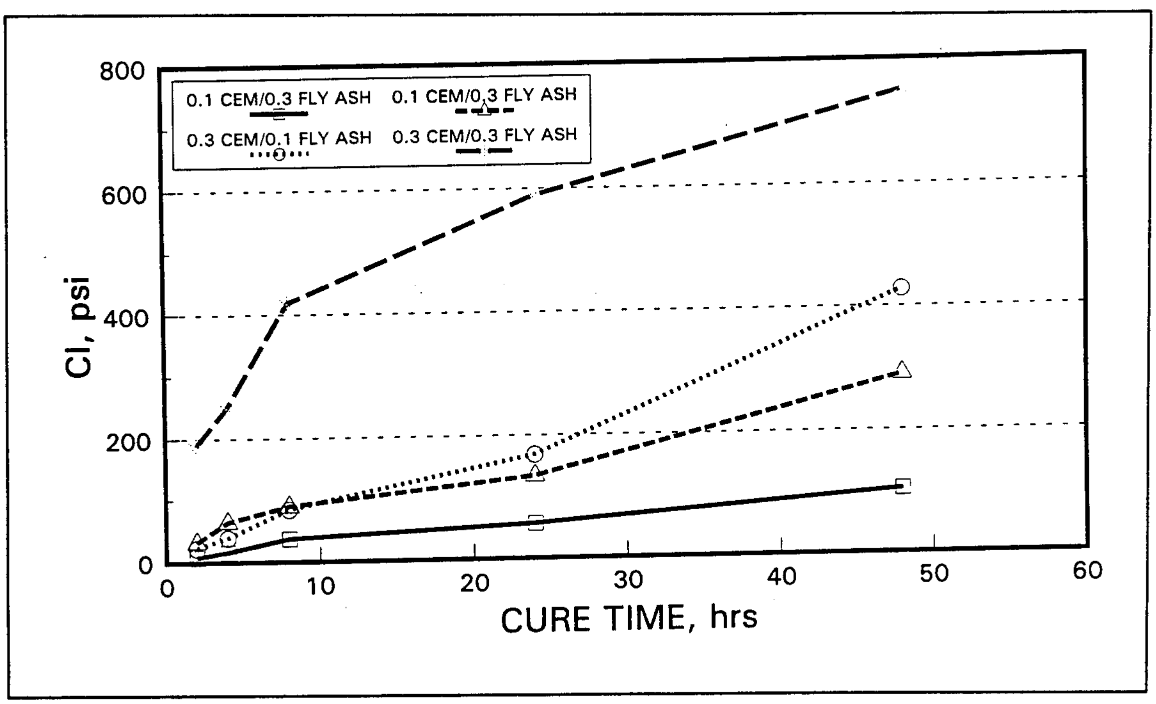

Figure 26. Average CI results for Soil 19 for cement/fly ash BSRs

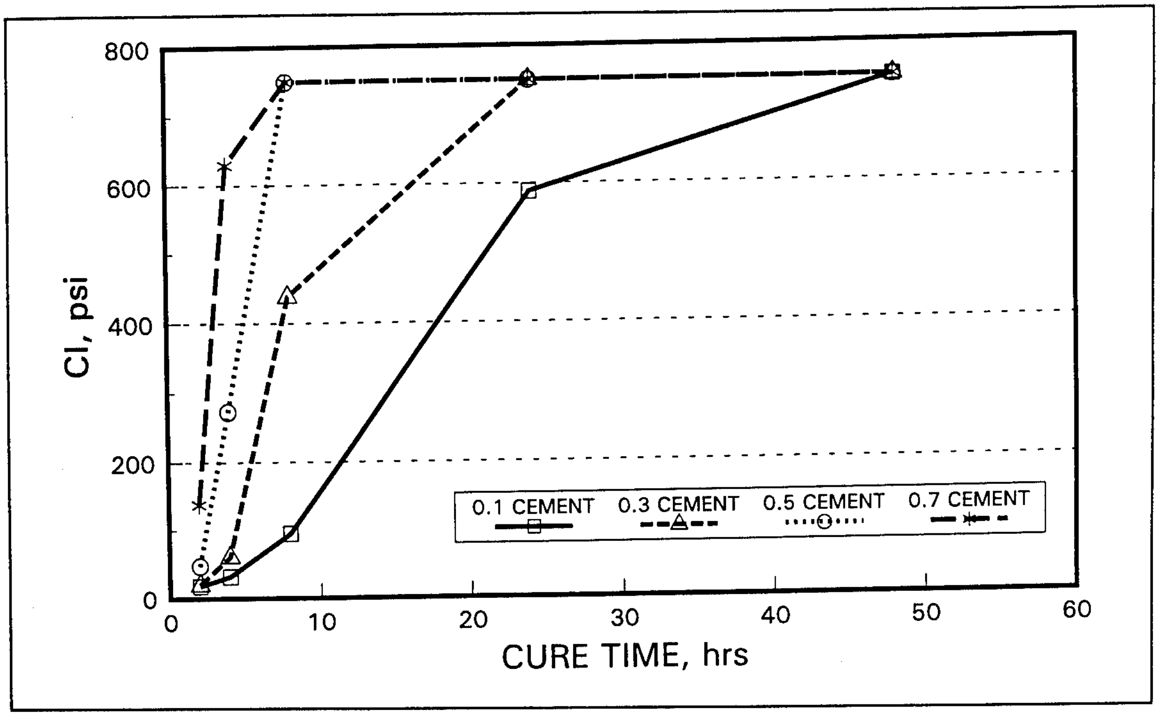

Figure 27. Average CI results for Soil 31 for cement BSRs

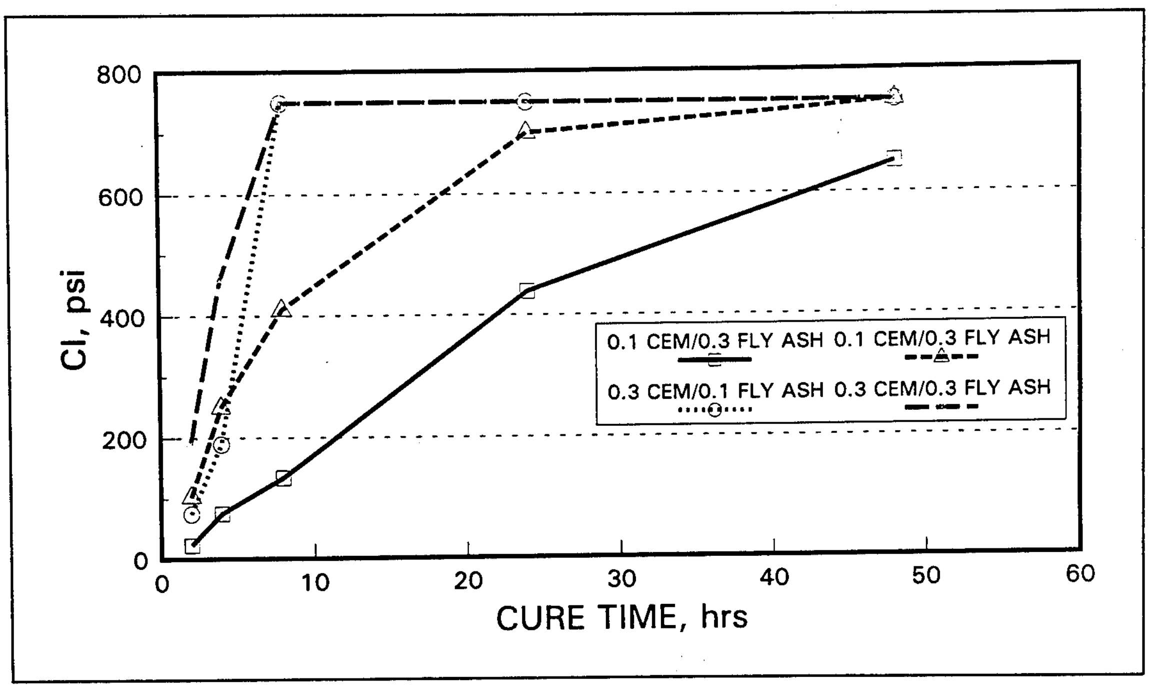

Figure 28. Average CI results for Soil 31 for cement/fly ash BSRs

Figures 27 and 28 present the results of the CI for Soil 31. All samples tested except for the 0.1/0.1 BSR achieved the maximum CI of 750 psi after 48 hr of cure. Also from Figures 27 and 28, it can be seen that as the BSR is increased, the set time for the sample increases.

UCS

Results of the UCS data for the detailed evaluation portion of this study are presented in Appendix C. The average results of the UCS for each BSR tested for each soil are presented in Figures 29-36. These results are presented as the UCS (reported in pounds per square inch) versus the cure time in days.

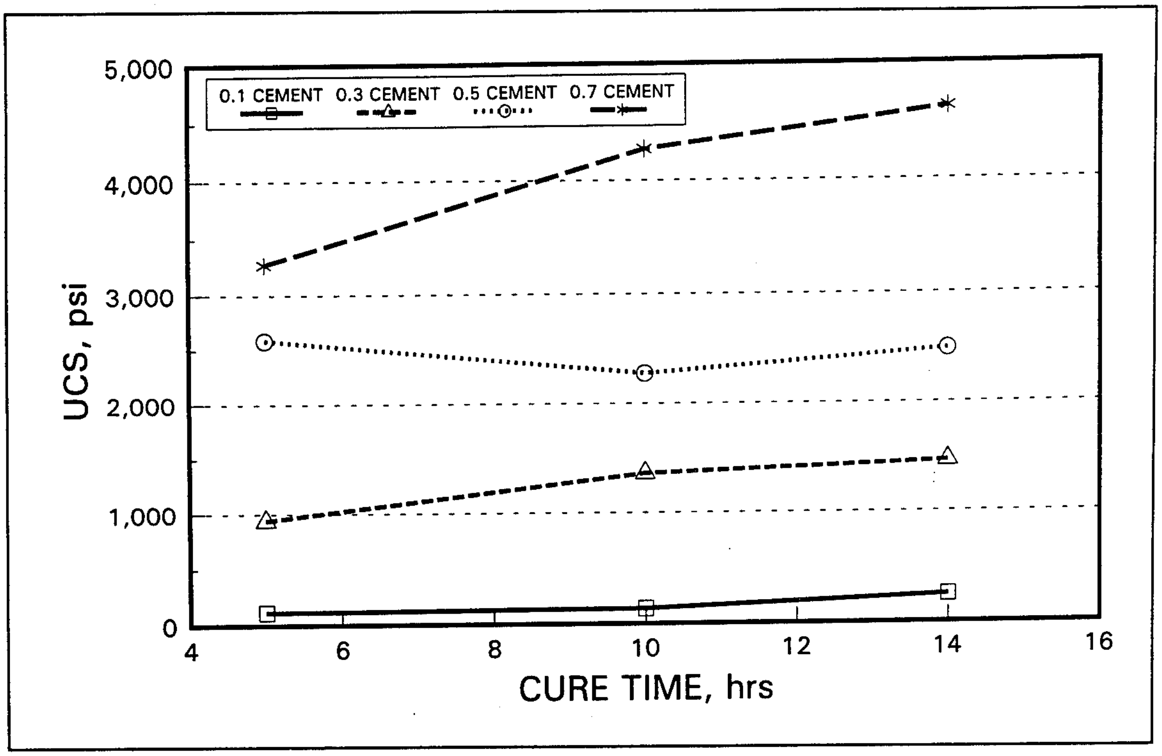

Figure 29. Average UCS results of Soil 2236 for cement BSRs

Figures 29 and 30 present the averaged UCS data for the cement and cement/fly ash BSRs, respectively, for Soil 2236. Both Figures 29 and 30 show that as the BSR is increased, the overall UCS increases. The higher BSRs had substantial UCS values above 2,000 psi. All BSRs evaluated for the UCS show that as the cure time increases, the UCS increases except for the 0.5 cement BSR and the 0.3/0.3 cement/fly ash BSR. The 0.5 cement BSR achieved its maximum UCS after 5 days of cure. The UCS for this BSR was lower at the 10-day cure time and appeared to remain relatively constant at the 14-day cure time. The 0.3/0.3 cement/fly ash BSR UCS achieved its maximum UCS at 10 days of cure. All samples evaluated for UCS for Soil 2236 exceeded the USEPA criterion of 50 psi for the UCS test.

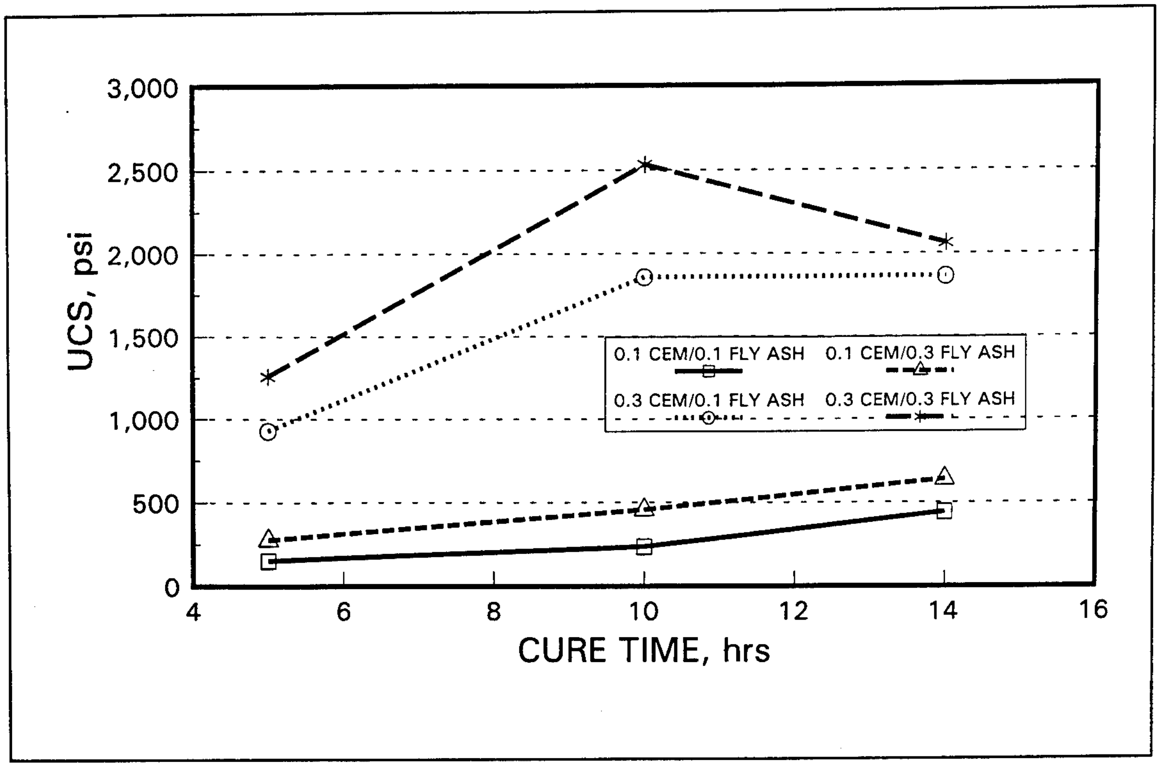

Figure 30. Average UCS results of Soil 2236 for cement/fly ash BSRs

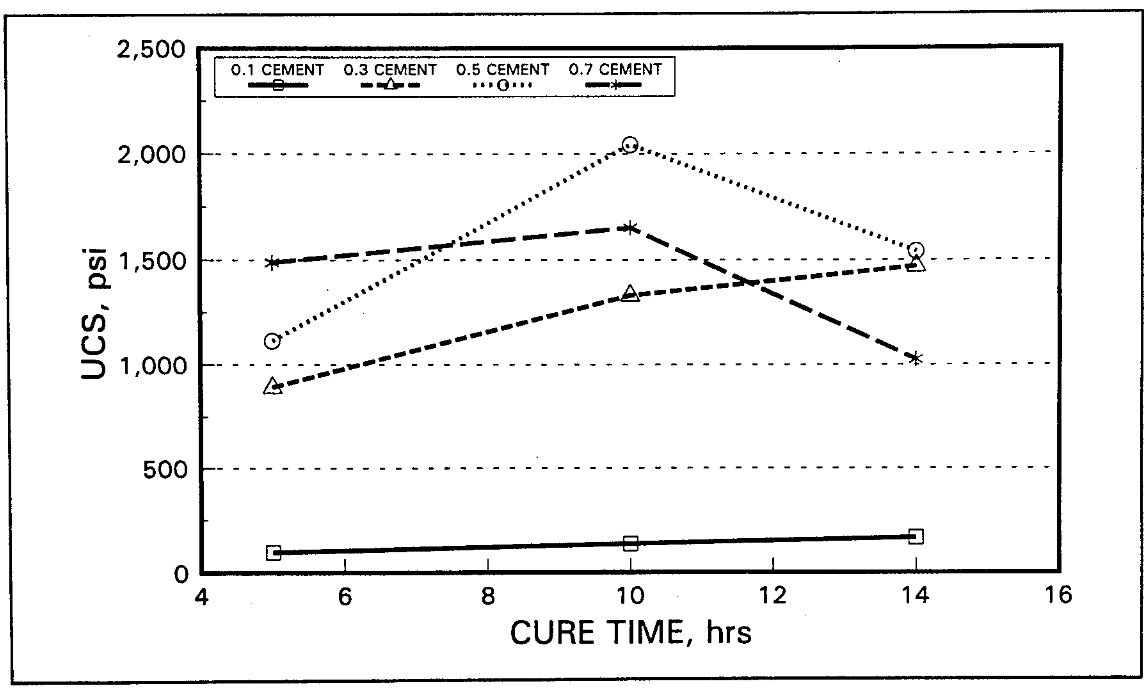

Figure 31. Average UCS results of Soil 15 for cement BSRs

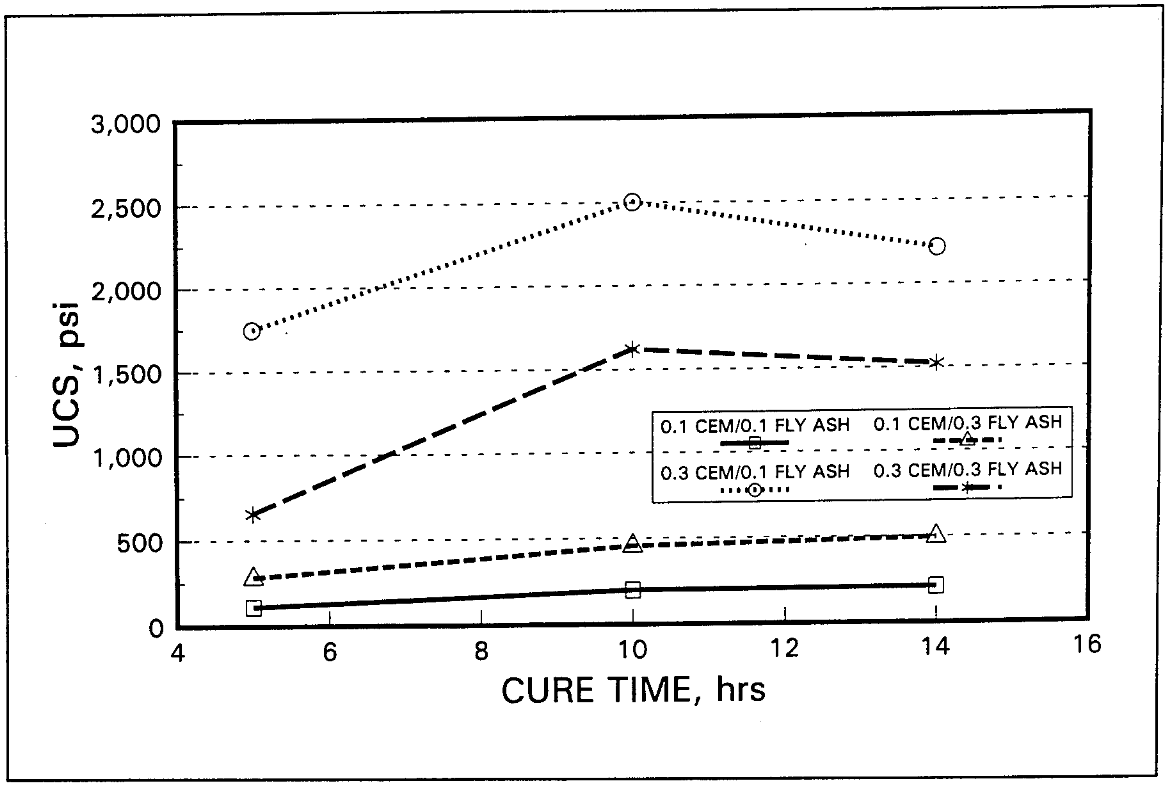

Figure 32. Average UCS results of Soil 15 for cement/fly ash BSRs

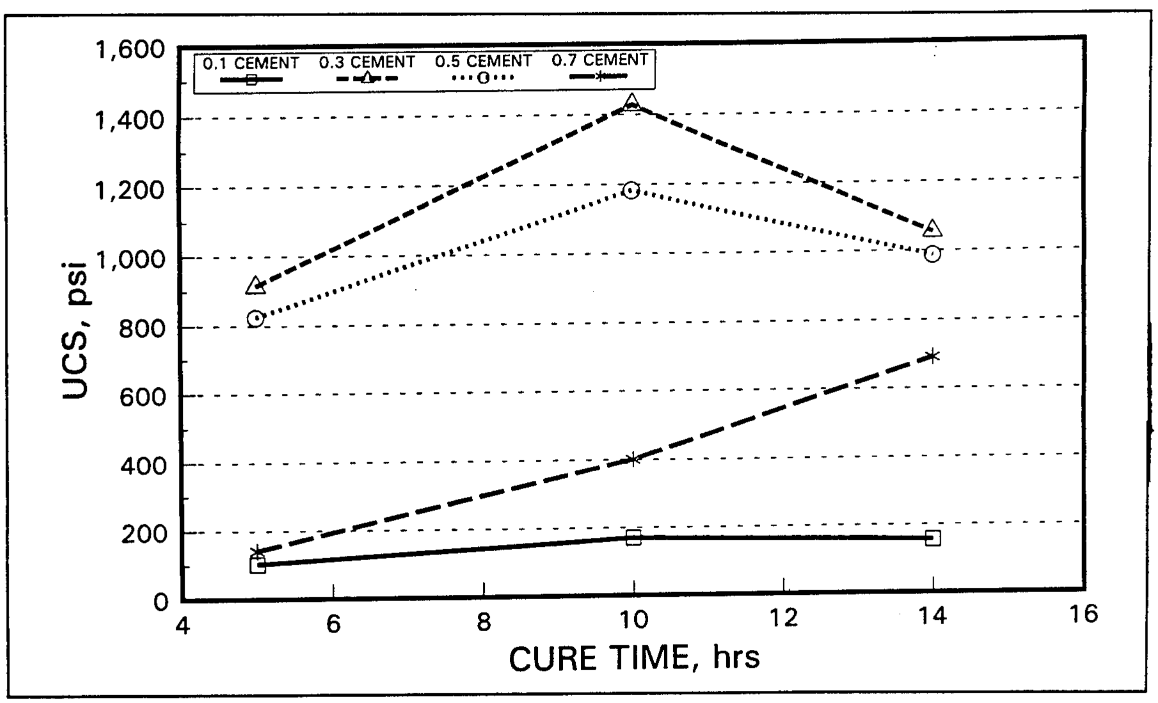

Figure 33. Average UCS results of Soil 19 for cement BSRs

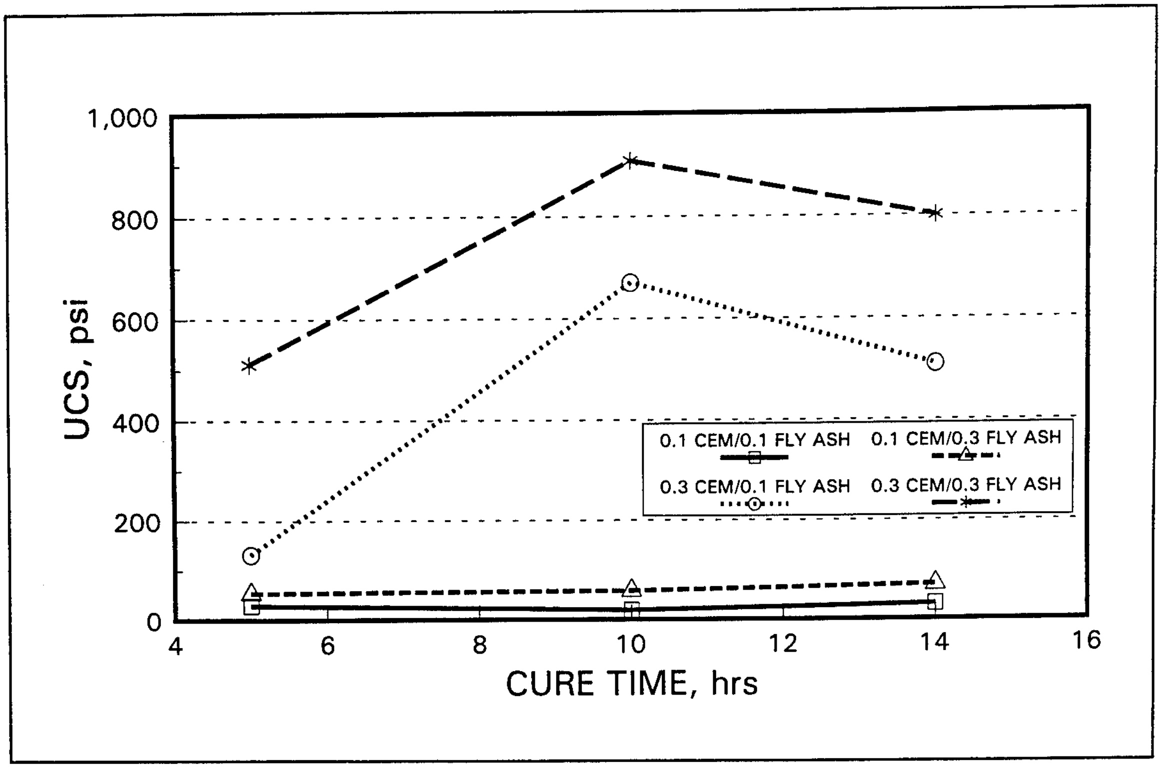

Figure 34. Average UCS results of Soil 19 for cement/fly ash BSRs

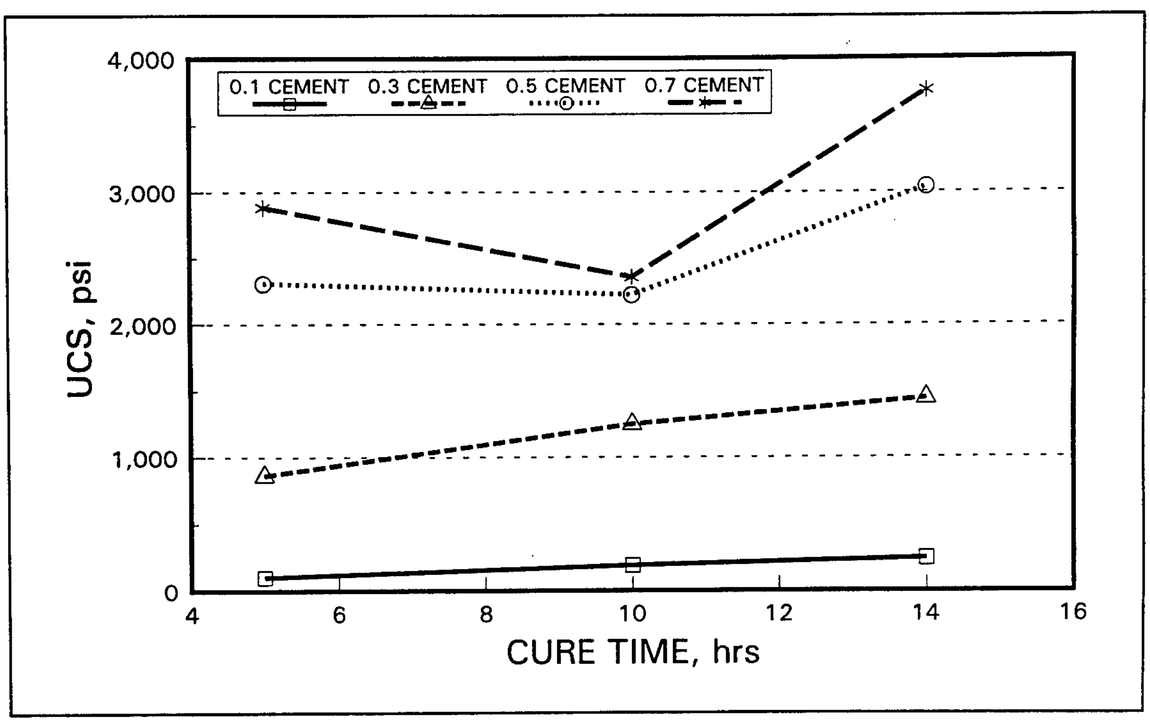

Figure 35. Average UCS results of Soil 31 for cement BSRs

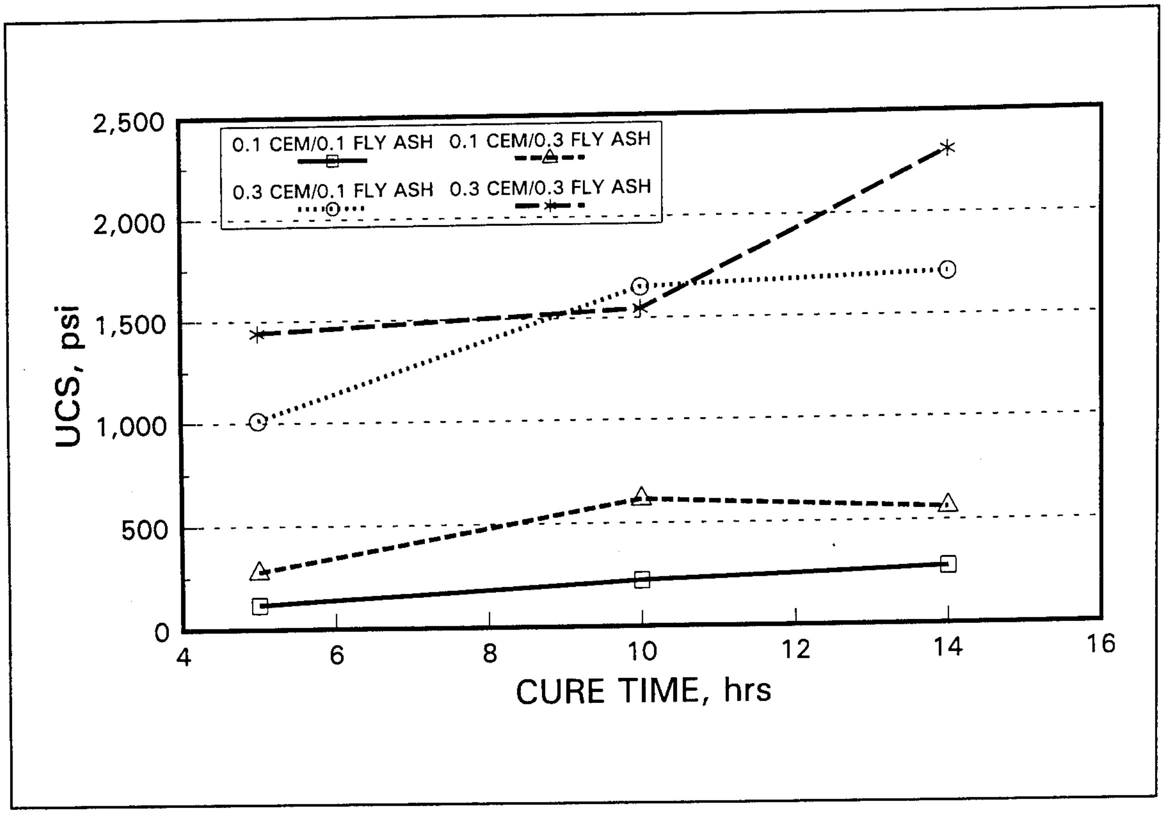

Figure 36. Average UCS results for Soil 31 for cement/fly ash BSRs

Figures 31 and 32 present the average UCS data for the cement and cement/fly ash BSRs for Soil 15. The higher BSRs for both the cement and cement/fly ash (0.5 and 0.7 cement and 0.3/0.1, and 0.3/0.3 cement/fly ash) achieved their maximum UCS at 10 days of cure. After the 10-day cure time, the UCS for all of these samples dramatically decreased. The UCS for the 0.5 and 0.7 cement BSRs decreased the most with an average decrease of 500 psi between the 10-day and 14-day test. The lower BSRs for both the cement and cement/fly ash had lower UCS, but indicated that they were continuing to gain strength at the end of the 14-day testing period. All samples evaluated exceeded the USEPA criterion of 50 psi for the UCS test.

Figures 33 and 34 present the UCS data for the cement and cement/fly ash BSRs for Soil 19. The BSRs of 0.3 and 0.5 cement achieved the highest UCS at 10 days of cure. After the 10-day cure time, the UCS decreased for both BSRs. The 0.7 cement BSR showed an increase in UCS during the 14-day cure time. According to Figure 33, the UCS for the 0.7 BSR continues to increase as cure time increases. The UCS for the 0.1 cement BSR did not increase a significant amount during the 14-day testing period. In Figure 34, the higher BSRs of 0.3/0.1 and 0.3/0.3 cement/fly ash gained the most strength during the UCS test. Both of these BSRs achieved their highest UCS at 10 days of cure. The UCS for these two BSRs decreased after the 10-day UCS and are shown to be decreasing as the cure time increases for the UCS test. The 0.1/0.1 and 0.1/0.3 BSRs did not gain much strength during the UCS

test. It should be noted that all samples exceeded the USEPA criterion of 50 psi for the UCS test except the 0.1/0.1 cement/fly ash BSR.

Figures 35 and 36 present the UCS data for the cement and cement/fly ash BSRs for Soil 31, respectively. Both figures show that as the BSR is increased, the UCS increases. Figure 35 indicates that as the cure time increases for the cement BSRs, the UCS also increases. Figure 36 indicates that for the cement/fly ash BSRs, the UCS for the BSRs of 0.3/0.3 and 0.1/0.1 increase as cure time increases. The BSRs of 0.1/0.3 and 0.3/0.1 cement/fly ash reach their highest UCS at 10 days of cure time and remain relatively constant as the cure time increases. All BSRs tested for UCS for Soil 31 exceeded the USEPA criterion of 50 psi for the UCS test.

Contaminant Release Testing

The TCLP was performed on all of the solidified/stabilized samples for each soil at a cure time of 2 days and 14 days. The results of the 2-day and 14-day TCLP were compared with the performance goals of the study to determine if the TCLP leachate met the performance criteria for the study. The results of the 2-day and 14-day TCLP for the detailed evaluation are presented in Appendix C. The average results of the 2-day TCLP for metals and explosives are presented in Tables 13 and 14 and discussed below.

Table 13 presents the results of the 2-day TCLP for metals. Table 13 shows that all of the cement BSRs evaluated for Soil 2236 passed the TCLP for the three metals of concern, cadmium, chromium, and lead. When compared with the TCLP for the untreated Soil 2236, the treated samples show a reduction in leaching of cadmium and lead. The chromium concentrations do not appear to be affected by the S/S of the soil. Cadmium was the only metal that failed to meet the TCLP criteria for the untreated soil. The S/S of Soil 2236 using any of the cement BSRs evaluated reduced the amount of cadmium leached from the soil so that the samples passed the TCLP and performance criteria for the study. The cement/fly ash BSRs evaluated for Soil 2236 show that the higher BSRs of 0.3/0.1 and 0.3/0.3 reduce the amount of both cadmium and lead leached from the S/S samples. While all samples tested passed the TCLP for chromium and lead, the lower BSRs of 0.1/0.1 and 0.1/0.3 did not pass the TCLP for cadmium. The average concentrations of cadmium for the 0.1/0.1 and 0.1/0.3 cement/fly ash BSRs were 2.40 and 4.33 mg/ℓ, respectively. Neither cadmium concentration meets the TCLP criterion of 1.0 mg/ℓ for cadmium. All BSRs evaluated for Soil 2236 meet the performance criteria for metals except for the 0.1/0.1 and 0.1/0.3 cement/fly ash BSRs.

The TCLP for all cement BSRs for Soil 15 shows that all samples evaluated using the cement and cement/fly ash BSRs passed the TCLP. Table 13 shows that for contaminants present in the TCLP leachate, the concentration of the contaminants in the leachate is reduced as the BSR is increased for both the cement and cement/fly ash. All BSRs evaluated during the detailed

Table 13
Two-Day TCLP Results for Metals for Detailed Evaluation Samples

BSR Ratio	mg/ℓ								
	As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
Soil 2236									
Cement									
0.1	NA[1]	NA	NA	<0.01	NA	0.390	<0.10	NA	NA
0.3	NA	NA	NA	<0.01	NA	0.384	<0.10	NA	NA
0.5	NA	NA	NA	<0.01	NA	0.090	<0.10	NA	NA
0.7	NA	NA	NA	<0.01	NA	0.084	<0.10	NA	NA
Cement/Fly Ash									
0.1/0.1	NA	NA	NA	2.40	NA	0.297	0.352	NA	NA
0.1/0.3	NA	NA	NA	4.33	NA	0.480	1.71	NA	NA
0.3/0.1	NA	NA	NA	<0.01	NA	1.624	<0.10	NA	NA
0.3/0.3	NA	NA	NA	<0.01	NA	0.234	<0.10	NA	NA
Soil 15									
Cement									
0.1	<0.20	3.78	<0.01	0.583	0.052	0.546	0.839	<0.10	0.004
0.3	<0.20	1.95	<0.01	0.062	<0.05	0.135	<0.10	<0.10	0.005
0.5	<0.20	2.10	<0.01	<0.01	<0.05	0.180	<0.10	<0.10	0.004
0.7	<0.20	2.77	<0.01	<0.01	<0.05	0.081	<0.10	<0.10	<0.003
Cement/Fly Ash									
0.1/0.1	0.126	2.96	<0.01	0.056	<0.05	0.185	<0.10	<0.10	0.004
0.1/0.3	0.161	2.51	<0.01	0.026	<0.05	0.157	<0.10	<0.10	0.003
0.3/0.1	<0.20	5.26	<0.01	<0.01	<0.05	0.155	<0.10	<0.10	<0.003
0.3/0.3	<0.20	3.82	<0.01	<0.01	<0.05	0.133	0.961	<0.10	<0.003
Soil 19									
Cement									
0.1	<0.20	4.47	NA	0.285	NA	<0.05	2.40	0.367	NA
0.3	<0.20	4.92	NA	<0.01	NA	0.074	<0.10	<0.10	NA
0.5	<0.20	3.44	NA	<0.01	NA	0.089	0.418	<0.10	NA
0.7	<0.20	2.75	NA	<0.01	NA	0.096	1.35	<0.10	NA

(Continued)

Note: Shaded area denotes that value is above the stated performance criteria for the study.
[1] NA: Sample was not analyzed for this metal.

Table 13 (Concluded)									
	mg/ℓ								
BSR Ratio	As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
Soil 19									
Cement/Fly Ash									
0.1/0.1	<0.20	5.10	NA	0.863	NA	<0.05	10.67	2.17	NA
0.1/0.3	<0.20	3.06	NA	1.16	NA	<0.05	14.61	0.117	NA
0.3/0.1	<0.20	2.40	NA	<0.01	NA	0.116	0.126	<0.10	NA
0.3/0.3	<0.20	2.43	NA	<0.01	NA	0.080	<0.10	<0.10	NA
Soil 31									
Cement									
0.1	NA	NA	NA	<0.01	NA	0.067	<0.10	NA	NA
0.3	NA	NA	NA	<0.01	NA	0.102	<0.10	NA	NA
0.5	NA	NA	NA	<0.01	NA	0.062	0.109	NA	NA
0.7	NA	NA	NA	<0.01	NA	0.068	<0.10	NA	NA
Cement/Fly Ash									
0.1/0.1	NA	NA	NA	<0.01	NA	0.054	<0.10	NA	NA
0.1/0.3	NA	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.3/0.1	NA	NA	NA	<0.01	NA	0.106	<0.10	NA	NA
0.3/0.3	NA	NA	NA	<0.01	NA	0.097	<0.10	NA	NA

evaluation show that the concentrations of metals present in the leachate for the untreated soil are reduced by the addition of the BSRs for the detailed evaluation. All samples evaluated during the detailed evaluation met the performance criteria for the 2-day TCLP.

All cement BSRs evaluated for Soil 19 passed the 2-day TCLP for the metals analyzed. Although the samples passed the TCLP, the cement BSR of 0.1 failed to meet the performance criteria for antimony. The average concentration of antimony found in the 0.1 cement BSR was 0.365 mg/ℓ. This is above the performance criterion for antimony of 0.146 mg/ℓ. Two of the cement/fly ash BSRs failed the TCLP for Soil 19. The cement/fly ash BSR of 0.1/0.1 failed the TCLP for lead with an average concentration of 10.67 mg/ℓ. This is above the TCLP criterion of 5.0 mg/ℓ for lead. Antimony was also elevated for the 0.1/0.1 BSR with an average concentration of 2.17 mg/ℓ. The cement/fly ash BSR of 0.1/0.3 failed the TCLP for cadmium and lead with an average concentration of 1.16 and 14.6 mg/ℓ, respectively. Because of these two BSRs failing the TCLP, they did not meet the performance criteria for this study.

Table 14
Average 2-Day TCLP Results of Explosive Compounds for Detailed Evaluation

BSR Ratio	HMX	RDX	TNB	DNB	Tetryl	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT	NB
	mg/ℓ										
Soil 15											
Cement											
0.1	1.73	18.8	2.33	<0.02	<0.05	1.55	<0.02	0.04	<0.02	0.02	ND[1]
0.3	3.35	20.40	0.29	<0.02	<0.05	14.74	0.07	0.05	<0.02	<0.02	ND
0.5	3.85	3.08	0.097	<0.02	<0.05	<0.02	0.152	0.04	<0.02	<0.02	ND
0.7	3.35	0.245	0.022	<0.02	<0.05	<0.02	0.126	0.03	<0.02	<0.02	ND
Cement/Fly Ash											
0.1/0.1	5.78	1.66	0.668	<0.02	<0.05	26.46	0.02	0.04	<0.02	0.04	ND
0.1/0.3	4.48	18.25	0.371	<0.02	<0.05	20.76	<0.02	0.025	<0.02	0.024	ND
0.3/0.1	0.59	<0.02	0.015	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3	0.217	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
Soil 19											
Cement											
0.1	0.062	0.041	0.014	<0.02	<0.05	0.646	<0.02	<0.02	<0.02	<0.02	ND
0.3	0.021	0.038	0.029	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.5	0.066	<0.02	0.018	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.7	0.084	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND

(Continued)

Note: Shaded area denotes that value is above stated performance criteria for the study.
[1] ND = Not detected.

Table 14 (Concluded)

BSR Ratio	mg/ℓ										
	HMX	RDX	TNB	DNB	Tetryl	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT	NB
Soil 19											
Cement/Fly Ash											
0.1/0.1	0.362	0.159	0.032	<0.02	<0.05	6.43	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.3	0.171	0.082	0.133	<0.02	<0.05	1.62	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.1	0.227	0.024	0.124	<0.02	<0.05	<0.02	0.012	<0.02	<0.02	<0.02	ND
0.3/0.3	0.228	0.094	0.121	<0.02	<0.05	0.63	<0.02	<0.02	<0.02	<0.02	ND
Soil 31											
Cement											
0.1	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.3	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.5	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.7	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
Cement/Fly Ash											
0.1/0.1	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.3	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.1	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND

The TCLP results for Soil 31 show that all BSRs evaluated for the detailed portion of this study passed the TCLP, meeting the performance criteria for cadmium, chromium, and lead.

Table 14 presents the average results of Replicates A and B for explosive compounds for the 2-day TCLP. The TCLP that was performed on Soil 2236 was not analyzed for explosive compounds in the TCLP leachate for the detailed evaluation. The TCLP leachate for Soil 15 contained many explosive compounds as indicated in Table 14. By comparing the explosive concentration in the TCLP leachate to the performance criteria for the study, all of the cement BSRs and two of the cement/fly ash BSRs failed to meet the proposed goal of 0.070 mg/ℓ of RDX in the TCLP leachate. RDX was present in the lower BSRs at high concentrations for both the cement and cement/fly ash BSRs and was reduced as the BSR increased. The 0.3/0.1 and 0.3/0.3 cement/fly ash BSRs were the only samples to meet the performance criteria for RDX. The concentration of 1,3,5-TNB in the TCLP leachate was above the performance criterion of 1.8 mg/ℓ for the 0.1 cement BSR. All other BSRs met the performance criteria for 1,3,5-TNB. TNT was the only other explosive compound detected in the TCLP leachate that did not meet the performance criterion of 0.280 mg/ℓ for Soil 15. The two lowest cement and cement/fly ash BSRs had TNT present in the TCLP leachate above the 0.280 mg/ℓ criterion. Since explosive compounds were detected in the TCLP leachate for all but the 0.3/0.1 and 0.3/0.3 cement/fly ash BSRs, only the two cement/fly ash BSRs met the performance criteria for Soil 15. It should be noted that Replicate B samples that failed to meet the performance criteria were the samples that had a low CI upon completion of the mixing of the samples. The Replicate B samples for the BSRs that failed to meet the criteria for the study turned red during the curing of the samples. When the TCLP was performed on these samples, the leachate from the TCLP was a red color. This red color is an indicator of explosive compounds in the leachate.

The 2-day TCLP results for Soil 19 show that all but one of the cement BSRs met the performance criteria for the concentration of explosives in the TCLP leachate. The 0.1 cement BSR failed to meet the criterion of 0.280 mg/ℓ of TNT in the TCLP leachate. All of the cement/fly ash BSRs except the 0.3/0.1 BSR failed to meet the proposed criteria for RDX and TNT. The concentration of RDX and TNT was above the criteria of 0.070 and 0.280, respectively, for the three cement/fly ash BSRs that did not meet the performance criteria for the study.

All of the BSRs evaluated for Soil 31 during the detailed evaluation met the performance criteria for explosive compounds in the TCLP leachate. There were no explosive compounds detected in the TCLP leachate for any of the samples.

Table 15 presents the average 14-day TCLP results for metals of the BSRs evaluated for the four soils. Table 15 shows that the TCLP leachate for all of the BSRs for Soils 2236, 15, and 31 met the performance criteria for metals for the study after 14 days of cure. The BSR of 0.1/0.1 cement/fly ash for

Table 15
Fourteen-Day TCLP Results for Metals for Detailed Evaluation Samples

BSR Ratio	mg/ℓ								
	As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
Soil 2236									
Cement									
0.1	NA[1]	NA	NA	0.548	NA	0.332	0.417	NA	NA
0.3	NA	NA	NA	0.649	NA	0.211	0.333	NA	NA
0.5	NA	NA	NA	0.622	NA	0.092	0.154	NA	NA
0.7	NA	NA	NA	0.154	NA	<0.05	<0.10	NA	NA
Cement/Fly Ash									
0.1/0.1	NA	NA	NA	0.918	NA	0.372	0.457	NA	NA
0.1/0.3	NA	NA	NA	0.634	NA	0.123	0.434	NA	NA
0.3/0.1	NA	NA	NA	0.666	NA	0.139	0.779	NA	NA
0.3/0.3	NA	NA	NA	0.372	NA	0.092	0.355	NA	NA
Soil 15									
Cement									
0.1	<0.20	4.69	<0.01	0.142	<0.05	0.155	<0.10	<0.10	0.003
0.3	<0.20	1.31	<0.01	<0.01	<0.05	0.105	<0.10	<0.10	0.003
0.5	<0.20	1.70	<0.01	<0.01	<0.05	0.056	<0.10	<0.10	<0.003
0.7	<0.20	1.91	<0.01	<0.01	<0.05	0.079	<0.10	<0.10	<0.003
Cement/Fly Ash									
0.1/0.1	<0.20	4.16	<0.01	0.192	<0.05	0.089	<0.10	<0.10	<0.003
0.1/0.3	<0.20	2.80	<0.01	0.199	<0.05	0.061	0.248	<0.10	<0.003
0.3/0.1	<0.20	2.57	<0.01	<0.01	<0.05	0.191	<0.10	<0.10	<0.003
0.3/0.3	<0.20	2.79	<0.01	0.555	<0.05	<0.05	<0.10	<0.10	<0.003
Soil 19									
Cement									
0.1	<0.20	7.50	NA	0.625	NA	<0.05	10.43	0.880	NA
0.3	<0.20	4.82	NA	0.070	NA	<0.05	0.146	0.214	NA
0.5	<0.20	2.81	NA	<0.01	NA	0.080	0.262	<0.10	NA
0.7	<0.20	2.16	NA	<0.01	NA	0.077	0.55	0.111	NA

(Continued)

Note: Shaded area denotes that value is above the stated performance criteria for the study.
[1] NA: Sample was not analyzed for this compound.

Table 15 (Concluded)									
	mg/ℓ								
BSR Ratio	As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
Soil 19									
Cement/Fly Ash									
0.1/0.1	<0.20	4.66	NA	0.748	NA	<0.05	4.52	0.119	NA
0.1/0.3	<0.20	2.99	NA	0.069	NA	0.092	<0.10	<0.10	NA
0.3/0.1	<0.20	4.23	NA	1.57	NA	<0.05	14.9	<0.10	NA
0.3/0.3	<0.20	5.14	NA	0.532	NA	<0.05	1.20	0.185	NA
Soil 31									
Cement									
0.1	NA	NA	NA	<0.01	NA	0.066	<0.10	NA	NA
0.3	NA	NA	NA	<0.01	NA	0.085	<0.10	NA	NA
0.5	NA	NA	NA	<0.01	NA	0.054	<0.10	NA	NA
0.7	NA	NA	NA	<0.01	NA	0.065	<0.10	NA	NA
Cement/Fly Ash									
0.1/0.1	NA	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.1/0.3	NA	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.3/0.1	NA	NA	NA	<0.01	NA	0.058	<0.10	NA	NA
0.3/0.3	NA	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA

Soil 2236 indicated that the average concentration of cadmium in the TCLP leachate was very near the TCLP limit and performance criterion of 1.0 mg/ℓ. The TCLP leachate for Soil 19 indicates that four BSRs did not meet the performance criterion for the study. The BSR of 0.1 and 0.3 cement failed the performance goal criterion of 0.146 mg/ℓ for antimony. Also, the 0.1 cement BSR failed to meet the TCLP criteria for lead. The 0.3/0.1 cement/fly ash BSR failed the TCLP for both cadmium and lead, while the 0.3/0.3 cement/fly ash BSR failed to meet the performance goal criteria for antimony. The remaining BSRs of 0.5 and 0.7 cement and 0.1/0.1 and 0.1/0.3 cement/fly ash met the performance criteria specified for the study for the treatment of metals.

A comparison of the 2-day and 14-day TCLP results for metals was performed to determine if an increase in cure time affected the leachability of the metal contaminants found in the soils. Soil 2236 showed that the concentrations for cadmium and lead were higher in the 14-day TCLP for the cement BSRs. From the comparison of the 2- and 14-day TCLP, it is possible that an increase in cure time for the cement samples could cause cadmium and lead to become mobile and leach from the solidified sample. The cement/fly ash

BSRs of 0.1/0.1 and 0.1/0.3 indicated that the concentration of cadmium in the TCLP leachate was decreased in the 14-day TCLP. The 2-day TCLP for the 0.1/0.1 and 0.1/0.3 cement/fly ash BSRs failed the TCLP for cadmium; but as the cure time increased, the two BSRs passed the 14-day TCLP and met the performance criteria for the study. The cement/fly ash BSRs of 0.3/0.1 and 0.3/0.3 showed an increase of cadmium in the 14-day TCLP leachate. All cement/fly ash BSRs decreased in chromium concentration for the 14-day TCLP. The cement/fly ash BSR of 0.1/0.3 showed a decrease in lead for the 14-day TCLP, while all other BSRs showed a slight increase for the 14-day TCLP.

The cement BSRs for Soil 15 showed a significant difference in the results of the 2- and 14-day TCLP for metals. The cement/fly ash BSRs showed an increase in cadmium being leached from the samples as time increased and a decrease in chromium for the 14-day TCLP. No other significant changes were noted for the concentrations of metals in the 2- and 14-day TCLP.

The cement BSRs for Soil 19 showed that the concentration of antimony increased for all BSRs, except the 0.5 cement, for the 14-day TCLP. The 0.1 cement BSR failed to meet the performance criteria for antimony for both the 2- and 14-day TCLP. Because the concentration of antimony increased as the cure time increased, the cement BSR of 0.3 failed to meet the performance criteria for the 14-day TCLP. The 0.1 cement BSR showed an increase in the lead concentration for the 14-day TCLP. This increase in lead caused the 0.1 cement BSR to fail the TCLP and not meet the performance criteria for the study. The cement/fly ash BSRs showed that the concentration of cadmium increased for all BSRs as cure time was increased except for the 0.1/0.3 BSR in which the cadmium concentration decreased for the 14-day TCLP. Since the cadmium concentration decreased for the 0.1/0.3 cement/fly ash BSR, this BSR passed the TCLP for the 14-day test time and met the performance criteria. The increase in the cadmium concentration caused the cement/fly ash BSR of 0.3/0.1 to fail the 14-day TCLP. The concentration of lead was decreased for the cement/fly ash BSRs of 0.1/0.1 and 0.1/0.3 for the 14-day TCLP. The concentration of lead in the 14-day TCLP was decreased so that these samples passed the TCLP and met the performance criteria for the study. The higher BSRs of 0.3/0.1 and 0.3/0.3 showed an increase in lead being leached from the samples as time increased. This increase in lead for the 14-day TCLP caused the cement/fly ash BSR of 0.3/0.1 to fail TCLP and not meet the performance criteria for the study. The concentration of antimony decreased for all cement/fly ash BSRs for the 14-day TCLP. This decrease in the concentration of antimony for the 14-day TCLP enabled the 0.1/0.1 BSR to meet the performance criteria for the study.

The comparison of the 2- and 14-day TCLP for Soil 31 showed no notable change in the concentrations of metals in the TCLP leachate.

Table 16 presents the average 14-day TCLP results for explosives of Soils 15, 19, and 31. All of the cement and cement/fly ash BSRs evaluated for Soil 15 fail to meet the performance goal of 0.070 mg/ℓ of RDX in the TCLP

Table 16
Average 14-Day TCLP Results of Explosive Compounds for Detailed Evaluation

BSR Ratio	mg/ℓ										
	HMX	RDX	TNB	DNB	Tetryl	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT	NB
Soil 15											
Cement											
0.1	5.42	18.93	0.113	<0.02	<0.05	10.03	0.201	0.038	<0.02	<0.02	ND[1]
0.3	3.71	11.97	0.194	<0.02	<0.05	0.340	0.209	0.028	<0.02	<0.02	ND
0.5	2.79	8.97	0.072	<0.02	<0.05	0.051	0.096	0.014	<0.02	<0.02	ND
0.7	0.566	0.507	0.135	<0.02	<0.05	0.045	0.061	<0.02	<0.02	<0.02	ND
Cement/Fly Ash											
0.1/0.1	4.94	26.27	0.370	<0.02	<0.05	32.46	0.015	<0.02	<0.02	<0.02	ND
0.1/0.3	3.78	27.40	0.157	<0.02	<0.05	15.46	<0.02	<0.02	<0.02	0.02	ND
0.3/0.1	0.344	0.769	0.026	<0.02	<0.05	0.295	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3	0.134	0.370	<0.02	<0.02	<0.05	0.022	<0.02	<0.02	<0.02	<0.02	ND
Soil 19											
Cement											
0.1	0.054	0.121	0.037	<0.02	<0.05	0.054	<0.02	<0.02	<0.02	<0.02	ND
0.3	0.049	0.094	0.041	<0.02	<0.05	1.73	<0.02	<0.02	<0.02	<0.02	ND
0.5	0.042	0.082	0.036	<0.02	<0.05	0.67	<0.02	<0.02	<0.02	<0.02	ND
0.7	0.072	0.069	0.039	<0.02	<0.05	4.38	<0.02	<0.02	<0.02	<0.02	ND

(Continued)

[1] ND = Not detected.
Note: Shaded area denotes that value is above stated performance criteria for the study.

Table 16 (Concluded)

BSR Ratio	mg/ℓ										
	HMX	RDX	TNB	DNB	Tetryl	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT	NB
Soil 19											
Cement/Fly Ash											
0.1/0.1	0.413	0.197	0.212	<0.02	<0.05	4.36	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.3	0.322	0.071	0.125	<0.02	<0.05	2.06	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.1	0.132	0.021	0.054	<0.02	<0.05	0.158	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3	0.069	0.059	0.075	<0.02	<0.05	1.86	<0.02	<0.02	<0.02	<0.02	ND
Soil 31											
Cement											
0.1	0.095	0.05	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.3	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.5	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.7	2.23	0.340	0.031	<0.02	<0.05	<0.02	0.081	<0.02	<0.02	<0.02	ND
Cement/Fly Ash											
0.1/0.1	0.021	0.053	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.3	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.1	<0.02	0.113	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3	<0.02	0.027	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND

leachate. Table 16 shows that as a general trend, the concentration of RDX in the TCLP leachate decreases as the BSR increases for both the cement and cement/fly ash BSRs. This trend of decreasing contaminant concentration versus increasing BSR is also evident for TNT. The 0.1 and 0.3 cement and all the cement/fly ash BSR except the 0.3/0.3 BSR fail to meet the performance criterion of 0.280 mg/ℓ of TNT in the TCLP leachate. Although some BSRs do meet the performance criteria for TNT, all BSRs fail to meet the criteria for RDX. Therefore, the cement and cement/fly ash BSRs do not demonstrate sufficient treatment of Soil 15 for explosive compounds.

The TCLP performed on the cement BSRs for Soil 19 shows that all samples failed to meet the performance criteria for RDX except for the 0.7 cement BSR. The concentration of RDX present in the TCLP leachate decreases as the cement BSR increases. All of the cement BSRs for Soil 19 failed to meet the performance criteria for TNT except for the 0.1 cement BSR. Since the 0.1 cement BSR failed to meet the performance criteria for RDX, and the 0.7 cement BSR failed to meet the criteria for TNT, none of the cement BSRs were demonstrated to achieve sufficient treatment of Soil 19. The cement/fly ash BSR of 0.3/0.1 was the only BSR to show effective treatment of Soil 19 for the cement/fly ash BSRs. The BSRs of 0.1/0.1 and 0.1/0.3 failed to meet the performance criterion for the concentration of both RDX and TNT in the TCLP leachate. The cement/fly ash BSR of 0.3/0.3 failed to meet the performance criteria for TNT in the TCLP leachate.

All of the cement and cement/fly ash BSRs evaluated for Soil 31 met the performance criteria for the explosive compounds except for the 0.7 cement BSR and the 0.3/0.1 cement/fly ash BSR. Both of these BSRs failed to meet the performance criterion of 0.070 mg/ℓ RDX in the TCLP leachate.

4 Summary

Based on the data from the testing of the untreated and treated soils, conclusions can be made about the effectiveness of S/S on the four soils. The untreated analysis of the soils indicates that the soils are not very cohesive. This is demonstrated by the samples crumbling and falling apart when the UCS samples were prepared at 85 percent of the Proctor density of the soils. All of the samples fell apart, and the UCS could not be performed on the four untreated soils. Chemical analysis of the untreated soils showed metals present in all four soils. Soil 31 analysis showed the presence of metals in the sample, but at low levels that were not of concern for potential leaching. Soils 2236, 15, and 19 had metals present at concentrations that failed to meet the TCLP and/or performance criteria for the study. Soils 15 and 19 indicated the presence of RDX, TNB, and TNT at concentrations that could present problems with leaching and the application of S/S to the soils. Soils 2236 and 31 had low concentrations of RDX and TNB in the soil. The TCLP that was performed on the untreated soils was analyzed for metals and explosives. Soil 2236 failed to pass the TCLP for cadmium. Soil 19 failed the TCLP for cadmium and lead. Both Soil 15 and Soil 31 passed the TCLP for all metals of concern for each soil. The analysis of the TCLP leachate for explosives shows that Soil 2236 and Soil 31 passed the TCLP and the performance criteria for the explosives of concern. Soils 15 and 19 failed to meet the performance criteria for RDX and TNT for the study.

Evaluation of the treated soils showed that S/S improves the handling properties of the soils. Nine tests were performed on the treated soils to evaluate their physical properties. The bulk density of all soils shows that an increase in BSR increases the bulk density. The 0.3 and 0.5 cement BSRs and the 0.3/0.1 cement/fly ash BSR for Soil 15 had the highest bulk density, but the bulk density did not increase as the BSR was increased. The higher BSRs showed that the bulk density decreases as the BSR increases above these ratios for Soil 15. The volume increase, which is based on the bulk density of the treated soil and the Proctor density of the untreated soil, indicates that as the BSR is increased, the volume of the solidified samples increases.

The paint filter test was performed on all of the BSRs immediately after mixing was completed. All BSRs of 0.1 and 0.3 cement and 0.1/0.1 cement/fly ash for all soils had evidence of free liquid pass the paint filter immediately after mixing was completed. Even though these samples failed the paint filter

test, no water was observed on the tops of the samples after the 48-hr cure time.

Workability, or slump, was performed on each BSR immediately after mixing. All of the 0.1 and 0.3 cement BSRs and 0.1/0.1 cement/fly ash BSR for all of the soils had slumps of 12 in. for the slump test. The slump test showed that as the BSR was increased for all of the soils, the slump was decreased for all of the BSRs for the soils.

The CI was performed on all of the BSRs for all four soils. All of the BSRs for Soil 2236 except the 0.1 cement and 0.1/0.1 cement/fly ash achieved the maximum CI of 750 psi after 48 hr of cure. The CI for Soil 15 showed that for the cement BSRs, the 0.3 BSR was the only sample to achieve the maximum CI of 750 psi. In contrast to what is usually observed in an S/S study, the higher cement BSRs of 0.5 and 0.7 had lower CIs. Replicates A and B for the 0.5 and 0.7 BSR did not duplicate each other for the CI test. Replicates A achieved the 750 psi for the CI, but Replicate B did not achieve as much strength. It was noted that Replicate B was soft, and the sample turned red during the 48-hr cure time. Since Replicates A and B were taken from different buckets, it is possible that Replicate B had a much higher concentration of explosives in the soil that retarded the set of the mixture. The cement/fly ash samples for Soil 15 all achieved the maximum 750 psi for the CI test except the 0.1/0.1 BSR. The cement/fly ash BSRs showed that as the BSR is increased for the soil, the CI increases for the samples.

The cement BSRs for Soil 19 showed similar results to the cement BSRs for Soil 15. The 0.3 cement BSR achieved the highest CI of 750 psi. The 0.5 and 0.7 cement BSR had the lowest CI for the cement samples. The 0.5 BSR replicates did not duplicate each other for the CI test. Replicate A had a CI of 125 psi, while Replicate B had a CI of 750 psi. Both replicates for the 0.7 cement BSR did duplicate each other for the CI test. All BSRs for Soil 31 showed that all BSRs except the 0.1/0.1 cement/fly ash BSR achieved the maximum 750 psi for the CI test. Soil 31 showed that as the BSR is increased, the CI also increases.

The UCS for Soil 2236 showed that as the BSR is increased for the soil, the UCS also increases. This was true for all BSRs evaluated except for the 0.5 cement BSR and the 0.3/0.3 cement/fly ash BSR. The 0.5 cement BSR achieved its highest UCS at 5 days of cure, while the 0.3/0.3 cement/fly ash BSR achieved its highest UCS at 10 days of cure. Soil 15 showed that the cement BSRs of 0.5 and 0.7 and the cement/fly ash BSRs of 0.3/0.1 and 0.3/0.3 had the highest UCS at 10 days of cure. The UCS for both cement BSRs decreased by 500 psi for 14-day testing. The UCS for both cement/fly ash BSRs also decreased at the 14-day test time. The 0.1 and 0.3 cement BSRs and the 0.1/0.1 and 0.1/0.3 cement/fly ash BSRs showed that the samples were increasing in strength as the cure time increased.

The UCS for Soil 19 for the cement BSRs showed that the 0.3 and 0.5 BSRs achieved the highest UCS at 10 days of cure, but decreased at the

14-day cure time. The UCS for the 0.7 cement BSR increased as the cure time increased, while the 0.1 cement BSR remained the same throughout the 14-day test period. The UCS for the 0.3/0.1 and 0.3/0.3 cement/fly ash BSRs achieved their highest UCS at 10 days of cure and decreased at the 14-day test time. The cement/fly ash BSR of 0.1/0.1 was the only sample that did not meet the USEPA criterion of 50 psi for the UCS test. The UCS for Soil 31 shows that for all of the cement BSRs and the 0.3/0.3 and 0.1/0.1 cement/fly ash BSR, the UCS increases as the cure time increases. The cement/fly ash BSRs of 0.1/0.3 and 0.3/0.1 achieved their highest UCS at 10 days of cure and remain relatively constant throughout the test.

All BSRs for the four soils were subjected to the TCLP at 2- and 14-day cure times. The results of the 2- and 14-day TCLP were compared to determine if cure time had an effect on the leachability of the contaminants and to determine which BSRs passed the TCLP and/or performance criteria for the S/S study. Table 17 presents the results of the 2- and 14-day TCLPs for determination of the metals and explosives meeting the performance criteria for the study. Table 17 presents the TCLP results regarding whether the compounds either passed the performance criteria or failed the performance criteria. The 2-day TCLP for Soil 2236 showed that all cement and cement/fly ash BSRs passed the TCLP for chromium and lead. The cement/fly ash BSRs of 0.1/0.1 and 0.1/0.3 failed to meet the TCLP criterion of 1.0 mg/ℓ for cadmium. All other BSRs passed the TCLP for cadmium. The 14-day TCLP for Soil 2236 showed that all cement and cement/fly ash BSRs met the TCLP and performance criteria for cadmium, chromium, and lead. It should be noted that the 14-day TCLP for the cement BSRs showed an increase in the concentration of cadmium and lead in the TCLP leachate. The concentration of cadmium for the 0.1/0.1 and 0.1/0.3 cement/fly ash BSRs decreased for the 14-day TCLP.

Both the 2- and 14-day TCLP for Soil 15 showed that the concentrations of metals in the TCLP leachate were below the TCLP limit and met the performance criteria for the S/S study. The 2-day TCLP for Soil 19 shows that all BSRs except the 0.1 cement and the 0.1/0.1 and 0.1/0.3 cement/fly ash BSRs met the TCLP and performance criteria for the S/S study. The 0.1 cement BSR failed to meet the performance criterion of 0.146 mg/ℓ of antimony in the TCLP leachate. The 0.1/0.1 cement/fly ash BSR failed to meet the TCLP limit of 5.0 mg/ℓ of lead and the performance criteria for antimony in the TCLP leachate. The 0.1/0.3 cement/fly ash BSR failed to meet the TCLP criteria of 1.0 and 5.0 mg/ℓ for cadmium and lead, respectively. The 14-day TCLP showed that the 0.1 and 0.3 cement BSR failed to meet the performance criteria for antimony in the TCLP leachate. The 0.1 cement BSR also failed to meet the TCLP criteria for lead. The 0.5 and 0.7 cement BSRs met the TCLP criteria and the performance criteria for the S/S study. The cement/fly ash BSR of 0.3/0.1 failed to meet the TCLP criteria for cadmium and lead. The 0.3/0.3 cement/fly ash BSR failed to meet the performance criteria for antimony in the TCLP leachate. The cement/fly ash BSRs of 0.1/0.1 and 0.1/0.3 met the TCLP and performance criteria for all metals for the S/S study for the 14-day TCLP.

Table 17
Summary of TCLP Results of S/S Study for UMDA Soils

BSR Ratio	Cure Time days	mg/ℓ												
		Sb <0.146	Cd <1.0	Cr <5.0	Pb <5.0	HMX <35.0	RDX <0.07	TNB <1.8	DNB <0.40	TNT <0.28	2,4-DNT <0.13	2,6-DNT <0.024	NB <2.0	Tetryl <40.0
Soil 2236														
0.1 Cem	2	NA[1]	P[2]	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
	14	NA	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
0.3 Cem	2	NA	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
	14	NA	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
0.5 Cem	2	NA	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
	14	NA	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
0.7 Cem	2	NA	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
	14	NA	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
0.1/0.1 Cem/FA	2	NA	F[3]	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
	14	NA	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
0.1/0.3 Cem/FA	2	NA	F	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
	14	NA	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
0.3/0.1 Cem/FA	2	NA	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
	14	NA	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
0.3/0.3 Cem/FA	2	NA	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
	14	NA	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA

(Sheet 1 of 4)

[1] NA: Denotes that compound was not analyzed for the TCLP test.
[2] P: Denotes that the concentration of the compound was below the performance criteria for the S/S study.
[3] F: Denotes that the concentration of the compound was above the performance criteria for the S/S study.

Table 17 (Continued)

BSR Ratio	Cure Time days	Sb <0.146	Cd <1.0	Cr <5.0	Pb <5.0	HMX <35.0	RDX <0.07	TNB <1.8	DNB <0.40	TNT <0.28	2,4-DNT <0.13	2,6-DNT <0.024	NB <2.0	Tetryl <40.0
		mg/ℓ												
Soil 15														
0.1 Cem	2	P	P	P	P	P	F	F	P	F	P	P	P	P
	14	P	P	P	P	P	F	P	P	F	P	P	P	P
0.3 Cem	2	P	P	P	P	P	F	P	P	F	P	P	P	P
	14	P	P	P	P	P	F	P	P	F	P	P	P	P
0.5 Cem	2	P	P	P	P	P	F	P	P	P	P	P	P	P
	14	P	P	P	P	P	F	P	P	P	P	P	P	P
0.7 Cem	2	P	P	P	P	P	F	P	P	P	P	P	P	P
	14	P	P	P	P	P	F	P	P	P	P	P	P	P
0.1/0.1 Cem/FA	2	P	P	P	P	P	F	P	P	F	P	P	P	P
	14	P	P	P	P	P	F	P	P	F	P	P	P	P
0.1/0.3 Cem/FA	2	P	P	P	P	P	F	P	P	F	P	P	P	P
	14	P	P	P	P	P	F	P	P	F	P	P	P	P
0.3/0.1 Cem/FA	2	P	P	P	P	P	P	P	P	P	P	P	P	P
	14	P	P	P	P	P	F	P	P	F	P	P	P	P
0.3/0.3 Cem/FA	2	P	P	P	P	P	P	P	P	P	P	P	P	P
	14	P	P	P	P	P	F	P	P	P	P	P	P	P
Soil 19														
0.1 Cem	2	F	P	P	P	P	P	P	P	F	P	P	P	P
	14	F	P	P	F	P	F	P	P	P	P	P	P	P

(Sheet 2 of 4)

Table 17 (Continued)

BSR Ratio	Cure Time days	Sb <0.146 (mg/ℓ)	Cd <1.0	Cr <5.0	Pb <5.0	HMX <35.0	RDX <0.07	TNB <1.8	DNB <0.40	TNT <0.28	2,4-DNT <0.13	2,6-DNT <0.024	NB <2.0	Tetryl <40.0
Soil 19 (Continued)														
0.3 Cem	2	P	P	P	P	P	P	P	P	P	P	P	P	P
	14	F	P	P	P	P	F	P	P	F	P	P	P	P
0.5 Cem	2	P	P	P	P	P	P	P	P	P	P	P	P	P
	14	P	P	P	P	P	F	P	P	F	P	P	P	P
0.7 Cem	2	P	P	P	P	P	P	P	P	P	P	P	P	P
	14	P	P	P	P	P	P	P	P	F	P	P	P	P
0.1/0.1 Cem/FA	2	F	P	P	F	P	F	P	P	F	P	P	P	P
	14	P	P	P	P	P	F	P	P	F	P	P	P	P
0.1/0.3 Cem/FA	2	P	F	P	F	P	F	P	P	F	P	P	P	P
	14	P	P	P	P	P	F	P	P	F	P	P	P	P
0.3/0.1 Cem/FA	2	P	P	P	P	P	P	P	P	P	P	P	P	P
	14	P	F	P	F	P	P	P	P	P	P	P	P	P
0.3/0.3 Cem/FA	2	P	P	P	P	P	F	P	P	F	P	P	P	P
	14	F	P	P	F	P	P	P	P	F	P	P	P	P
Soil 31														
0.1 Cem	2	P	P	P	P	P	P	P	P	P	P	P	P	P
	14	P	P	P	P	P	P	P	P	P	P	P	P	P
0.1 Cem	2	P	P	P	P	P	P	P	P	P	P	P	P	P
	14	P	P	P	P	P	P	P	P	P	P	P	P	P

(Sheet 3 of 4)

Table 17 (Concluded)

BSR Ratio	Cure Time days	Sb <0.146	Cd <1.0	Cr <5.0	Pb <5.0	HMX <35.0	RDX <0.07	TNB <1.8	DNB <0.40	TNT <0.28	2,4-DNT <0.13	2,6-DNT <0.024	NB <2.0	Tetryl <40.0
		mg/ℓ												
Soil 31 (Continued)														
0.3 Cem	2	P	P	P	P	P	P	P	P	P	P	P	P	P
	14	P	P	P	P	P	P	P	P	P	P	P	P	P
0.5 Cem	2	P	P	P	P	P	P	P	P	P	P	P	P	P
	14	P	P	P	P	P	P	P	P	P	P	P	P	P
0.7 Cem	2	P	P	P	P	P	P	P	P	P	P	P	P	P
	14	P	P	P	P	P	F	P	P	P	P	P	P	P
0.1/0.1 Cem/FA	2	P	P	P	P	P	P	P	P	P	P	P	P	P
	14	P	P	P	P	P	P	P	P	P	P	P	P	P
0.1/0.3 Cem/FA	2	P	P	P	P	P	P	P	P	P	P	P	P	P
	14	P	P	P	P	P	P	P	P	P	P	P	P	P
0.3/0.1 Cem/FA	2	P	P	P	P	P	P	P	P	P	P	P	P	P
	14	P	P	P	P	P	P	P	P	P	P	P	P	P
0.3/0.3 Cem/FA	2	P	P	P	P	P	P	P	P	P	P	P	P	P
	14	P	P	P	P	P	P	P	P	P	P	P	P	P

(Sheet 4 of 4)

All of the BSRs evaluated for Soil 31 for the 2- and 14-day TCLP met the TCLP and performance criteria for cadmium, chromium, and lead.

The TCLP leachate for Soil 2236 was not analyzed for explosives due to the results of the untreated TCLP and the IST TCLPs. The 2-day TCLP for Soil 15 showed that all cement BSRs failed to meet the performance criterion of 0.070 mg/ℓ of RDX in the TCLP leachate. The 0.1 and 0.3 cement BSRs also failed to meet the performance criterion of 0.280 mg/ℓ of TNT in the TCLP leachate. The cement/fly ash BSRs of 0.1/0.1 and 0.1/0.3 failed to meet the performance criteria for RDX and TNT. The cement/fly ash BSRs of 0.3/0.1 and 0.3/0.3 were the only BSRs for Soil 15 that met the performance criteria for the 2-day TCLP. The 14-day TCLP for Soil 15 shows that all cement and cement/fly ash BSRs failed to meet the performance criteria for RDX. The cement BSRs of 0.1 and 0.3 and the cement/fly ash BSRs of 0.1/0.1, 0.1/0.3, and 0.3/0.1 also failed to meet the performance criteria for TNT. From the 14-day TCLP for Soil 15, it can be seen that for both RDX and TNT, the concentration of both contaminants decreases as the BSR increases.

The 2-day TCLP for Soil 19 shows that all cement BSRs except for the 0.1 BSR met the performance criteria for the S/S study. The 0.1 cement BSR failed to meet the performance criteria for TNT in the TCLP leachate. The cement/fly ash BSR of 0.3/0.1 was the only cement/fly ash BSR that did not meet the performance criteria for the S/S study. The 0.3/0.1 BSR failed to meet the performance criteria for both RDX and TNT. The 14-day TCLP shows that all of the cement BSRs failed to meet the performance criteria for TNT. The cement BSRs of 0.1, 0.3, and 0.5 also failed to meet the performance criteria for RDX. The cement/fly ash BSR of 0.1/0.1 and 0.1/0.3 failed to meet the performance criteria for RDX and TNT in the TCLP leachate. The cement/fly ash BSR of 0.3/0.3 failed to meet the performance criteria for TNT. The 0.3/0.1 cement/fly ash BSR was the only BSR to meet the performance criteria for the TCLP for the 14-day TCLP for Soil 19.

The 2-day TCLP for Soil 31 shows that all cement and cement/fly ash BSRs met the performance criteria for the TCLP leachate. The 14-day TCLP shows that the 0.7 cement BSR and the 0.3/0.1 cement/fly ash BSR failed to meet the performance criteria for RDX in the TCLP leachate. All other BSRs for Soil 31 met the performance criteria for the S/S study.

5 Additional Studies for Soils 15 and 19

Based on the results of the TCLP for Soils 15 and 19, the Seattle District decided that additional studies were required to determine a mixture for the soils that would meet the performance criteria for cleanup of soils. Since the initial study indicated that Soil 31 contained low concentrations of metals and explosives, it was decided that Soil 31 would be mixed with Soils 15 and 19 and solidified. Once the soils were solidified, they would then be subjected to the TCLP to determine if the mixture of the soils could meet the performance criteria for the cleanup of the two sites.

Soil 15 was mixed with Soil 31 at four weight ratios, 100-percent Soil 15/0-percent Soil 31, 75-percent Soil 15/25-percent Soil 31, 50-percent Soil 15/50-percent Soil 31, and 25-percent Soil 15/75-percent Soil 31. The same weight ratios were used for the mixture of Soils 19 and 31. The mixing of the soils was accomplished by first homogenizing two 5-gal containers of each soil by using a Hobart K455S mixer. Once the mixing of the two containers of each soil was accomplished, the soils were mixed with Soil 31 at the weight ratios previously mentioned. These mixtures of soils were mixed in a Hobart K455S mixer for 10 min and then placed in clean 5-gal containers and stored at 4 °C until needed for testing.

Chemical Tests of Untreated Soil Mixtures

Once the soils were mixed, samples were taken of each soil mixture in triplicate to determine the concentration of metals and explosives present in the soils. Also, a TCLP was performed in triplicate on each mixture to determine the amount of leachable metals and explosives present in the soils. All metals and explosives that were previously tested for the soils were analyzed for the soil mixtures.

Preparation of Test Specimens

A single binder ratio of 0.3 Portland cement Type I and 0.1 Type F fly ash was used to solidify the two soil mixtures, Soil 15/Soil 31 and Soil 19/Soil 31. The same procedure for the mixing of the samples was used as specified in the Methods and Materials section of this report.

Physical and Chemical Tests

The CI test was the only physical test performed on the soils mixtures. The procedure for CI is presented in the Methods and Materials section of this report.

The TCLP was performed on all of the solidified soil mixtures in triplicate. The procedure of the TCLP is outlined in the Methods and Materials section of this report.

Results of Additional Studies

Untreated chemical results

Table 18 presents the average metal concentrations for the mixture of Soils 15 and 31 and Soils 19 and 31. As expected with the mixing of the soils, the concentrations of metals found in the soil mixtures showed a general decrease in concentration as more of Soil 31 was added to Soil 15 and Soil 19. The 100-percent Soil 15 and 100-percent Soil 19 generally had the highest concentration of metals for the soils evaluated. As more of Soil 31 was added to Soils 15 and 19, the concentration of the metals decreased. Chromium was found to vary in the samples tested with the 75-percent Soil 15 and the 75-percent Soil 19, with 25-percent Soil 31 having the highest concentration of chromium. A greater concentration of all metals was noticed in the samples

Table 18
Average Metal Concentrations of Additional Soil Mixtures

Soil Mixture	mg/kg								
	As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
100% Soil 15	10.8	396	0.21	45.3	11.6	74.0	500	15.6	65.0
75% 15/25% 31	5.4	306	0.20	27.3	10.3	83.0	220	18.0	50.0
50% 15/50% 31	5.7	263	0.21	22.0	10.7	65.3	230	20.8	65.6
25% 15/75% 31	3.4	180	0.21	10.0	8.9	36.3	143	9.4	12.2
100% Soil 19	7.9	2,466	0.20	65.0	6.3	16.7	7,433	92.6	11.3
75% 19/25% 31	10.5	2,866	0.18	84.3	8.0	20.0	5,466	87.0	20.6
50% 19/50% 31	4.0	1,600	0.18	34.0	8.4	14.6	2,733	60.0	20.0
25% 19/75% 31	3.0	893	0.19	15.6	7.9	11.0	2,500	32.3	19.6

for the additional studies than was present for the initial phase of the study except for beryllium and antimony. Soil 19 contained a much greater concentration of lead for the additional study samples than did the Soil 19 tested for the initial phase of the study. Average concentrations of lead found in Soil 19 for the additional studies was 7,433 mg/kg, while Soil 19 for the initial samples contained an average of 3,450 mg/kg.

Table 19 presents the average explosive concentrations of the soil mixtures of Soil 15 and Soil 31 and for Soil 19 and Soil 31. Table 19 shows that the 100-percent Soils 15 and 19 had the highest concentration of HMX, RDX, TNB, and TNT. As Soils 15 and 19 were mixed with varying amounts of Soil 31, the concentration of explosives decreased in the soil. This is expected since Soil 31 did not indicate the presence of explosive compounds present in the soil.

As previously discussed in the initial phase of the study, Soil 15 for the additional S/S study contained a high concentration of RDX and TNT with concentrations of 3,867 and 5,037 mg/kg, respectively. As Soil 15 was mixed with varying ratios of Soil 31, the concentration of all explosive compounds decreased. Soil 19 did not contain as high a concentration of explosive compounds as did Soil 15. Soil 19 had average RDX and TNT concentrations of 9.6 and 97.4 mg/kg, respectively. All explosive compounds for Soil 19 except for 4A-DNT and 2A-DNT decreased as higher ratios of Soil 31 were mixed with Soil 19.

Table 20 presents the average results for metals for the TCLP performed on the untreated soil mixtures. All of the metals analyzed for Soil 15/31 were below the TCLP limits and the performance criteria for the S/S study. Table 20 shows that as more of Soil 31 is mixed with Soil 15, the average concentration of metals decreases in the TCLP leachate. The TCLP results of Soils 19/31 show that all of the mixtures of these two soils failed to meet the TCLP and performance criteria for cadmium, lead, and antimony.

Table 21 presents the average results of explosives analysis of the TCLP performed on the untreated soil mixtures. RDX and TNT were present in the TCLP leachate for all four of the Soil 15/Soil 31 mixtures. The RDX concentration found in the TCLP leachate for Soil 15 did not decrease as expected as Soil 31 was mixed with Soil 15. The 100-percent Soil 15 had an RDX concentration of 33.8 mg/ℓ in the TCLP leachate, while the 25-percent Soil 15/75-percent Soil 31 had an RDX concentration of 29.8 mg/ℓ in the TCLP leachate. It was expected that for all Soil 15/Soil 31 mixtures, the concentration of RDX and TNT would decrease by 25 percent as more Soil 31 was mixed with Soil 15. Expected RDX concentrations for the 75-percent Soil 15/25-percent Soil 31, 50-percent Soil 15/50-percent Soil 31, and 25-percent Soil 15/75-percent Soil 31 were 25.3, 16.9, and 8.45 mg/ℓ, respectively. Average results of the TCLP performed on the untreated Soil 15/Soil 31 mixtures show that the RDX concentration decreases by only an average of 1.0 mg/ℓ as the concentration of Soil 15 is decreased by 25 percent. The

Table 19
Average Explosive Compounds in Additional Soil Mixtures

Soil Mixture	mg/kg										
	HMX	RDX	TNB	DNB	TETRYL	TNT	4A-DNT	2A-DNT	2, 6-DNT	2, 4-DNT	NB
100% Soil 15	609.0	3,867.0	39.5	<25.0	<65.0	5,037.0	<25.0	<25.0	<26.0	<25.0	ND[1]
75% 15/25% 31	493.0	3,056.0	31.0	<25.0	<65.0	4,510.0	<25.0	<25.0	<26.0	<25.0	ND
50% 15/50% 31	351.0	2,070.0	20.1	<25.0	<65.0	2,870.0	<25.0	<25.0	<26.0	<25.0	ND
25% 15/75% 31	168.0	1,036.0	10.3	<25.0	<65.0	1,463.0	<25.0	<25.0	<26.0	<25.0	ND
100% Soil 19	3.89	9.6	15.8	<25.0	<65.0	97.4	0.797	0.643	<26.0	0.142	ND
75% 19/25% 31	2.78	5.82	12.8	<25.0	<65.0	44.3	0.560	0.392	<26.0	0.186	ND
50% 19/50% 31	1.87	4.10	8.00	<25.0	<65.0	32.2	0.681	0.442	<26.0	<25.0	ND
25% 19/75% 31	1.14	2.62	4.14	<25.0	<65.0	23.5	0.713	0.383	<26.0	<25.0	ND

[1] ND = Not detected.

Table 20 Average TCLP Metal Concentrations of Additional Soil Mixtures									
	mg/ℓ								
Soil Mixture	As <5.0	Ba <100.0	Be <0.004	Cd <1.0	Co na[1]	Cr <5.0	Pb <5.0	Sb <0.146	Tl na
100% Soil 15	0.0049	8.21	<0.002	0.757	0.052	0.053	0.737	0.0225	<0.004
75% 15/25% 31	<0.004	11.4	<0.002	0.230	0.044	0.026	0.209	0.0090	<0.004
50% 15/50% 31	0.004	4.52	<0.002	0.281	0.054	0.019	0.178	0.0074	<0.004
25% 15/75% 31	0.004	2.20	<0.002	0.131	0.041	<0.016	0.122	0.0090	<0.004
100% Soil 19	0.017	15.7	<0.002	1.86	<0.03	0.017	11.5	1.41	<0.004
75% 19/25% 31	0.029	14.7	<0.002	1.55	0.038	<0.016	30.3	1.19	<0.004
50% 19/50% 31	0.010	11.3	<0.002	1.24	0.031	0.018	50.8	1.34	<0.004
25% 19/75% 31	0.009	7.04	<0.002	0.835	0.039	0.018	26.9	0.506	<0.004

Note: Shaded area denotes sample failed to meet performance criteria for the study.
[1] na = No criteria have been set for the compound for the TCLP test.

results for TNT showed that the concentration of TNT for the 75-percent Soil 15/25-percent Soil 31 decreased by approximately 25 percent from the 100-percent Soil 15 concentration of TNT found in the TCLP leachate. As more of Soil 31 was mixed with Soil 15, the average TNT concentration in the TCLP leachate increased. As expected, both RDX and TNT failed to meet the performance criteria for all mixtures of the untreated Soil 15/Soil 31 mixtures.

The results of the TCLP for the untreated Soil 19/Soil 31 mixtures indicate that the concentration of RDX and TNT were much lower than the result of the Soil 15/Soil 31 mixtures. RDX concentrations for the 100-percent Soil 19 and the 75-percent Soil 19/25-percent Soil 31 are above the performance criteria established for the study. The 50-percent Soil 19/50-percent Soil 31 and 25-percent Soil 19/75-percent Soil 31 samples passed the TCLP performance goals for the concentraion of RDX found in the TCLP leachate. Although some of the untreated soil mixtures passed the TCLP for RDX, none of the mixtures passed the TCLP performance criteria for TNT.

Physical and chemical results of test specimens

Figure 37 presents the average CI results for the Soil 15/Soil 31 test specimens. All samples tested achieved the maximum CI of 750 psi after 48 hr of cure. The 50-percent Soil 15/50-percent Soil 31 mixture and the 25-percent Soil 15/75-percent Soil 31 mixture had similar results for the CI test. Each of these samples achieved the maximum CI of 750 psi after 24 hr of cure. The 75-percent Soil 15/25-percent Soil 31 mixture and 100-percent Soil 15 samples did not achieve the maximum CI of 750 psi until 48 hr of cure.

Figure 38 presents the average CI results for the Soil 19/Soil 31 test specimens. All samples except the 100-percent Soil 19 samples achieved the

Table 21
Average TCLP Concentration of Explosive Compounds in Additional Soil Mixtures

Soil Mixture	mg/ℓ										
	HMX <35.0	RDX <0.07	TNB <1.8	DNB <0.40	TETRYL <40.0	TNT <1.8	4A-DNT na[1]	2A-DNT na[1]	2, 6-DNT <0.024	2, 4-DNT <0.13	NB <2.0
100% Soil 15	6.31	33.8	0.450	<0.020	<0.050	30.3	0.917	1.00	<0.020	0.021	ND[2]
75% 15/25% 31	5.81	32.4	0.246	<0.020	<0.050	22.5	0.949	1.05	<0.020	<0.020	ND
50% 15/50% 31	4.63	30.8	0.223	<0.020	<0.050	24.7	0.811	1.04	<0.020	<0.020	ND
25% 15/75% 31	3.16	29.8	0.211	<0.020	<0.050	29.1	0.421	0.444	<0.020	<0.020	ND
100% Soil 19	0.071	0.105	0.112	<0.020	<0.050	0.693	0.013	<0.020	<0.020	<0.020	ND
75% 19/25% 31	0.063	0.113	0.104	<0.020	<0.050	0.921	<0.020	<0.020	<0.020	<0.020	ND
50% 19/50% 31	0.039	0.065	0.077	<0.020	<0.050	0.614	<0.020	<0.020	<0.020	<0.020	ND
25% 19/75% 31	0.027	0.061	0.036	<0.020	<0.050	0.219	<0.020	<0.020	<0.020	<0.020	ND

[1] na = No criteria have been set for the compound for the TCLP test.
[2] ND = Not detected.
Note: Shaded area denotes that sample failed to meet performance criteria for the study.

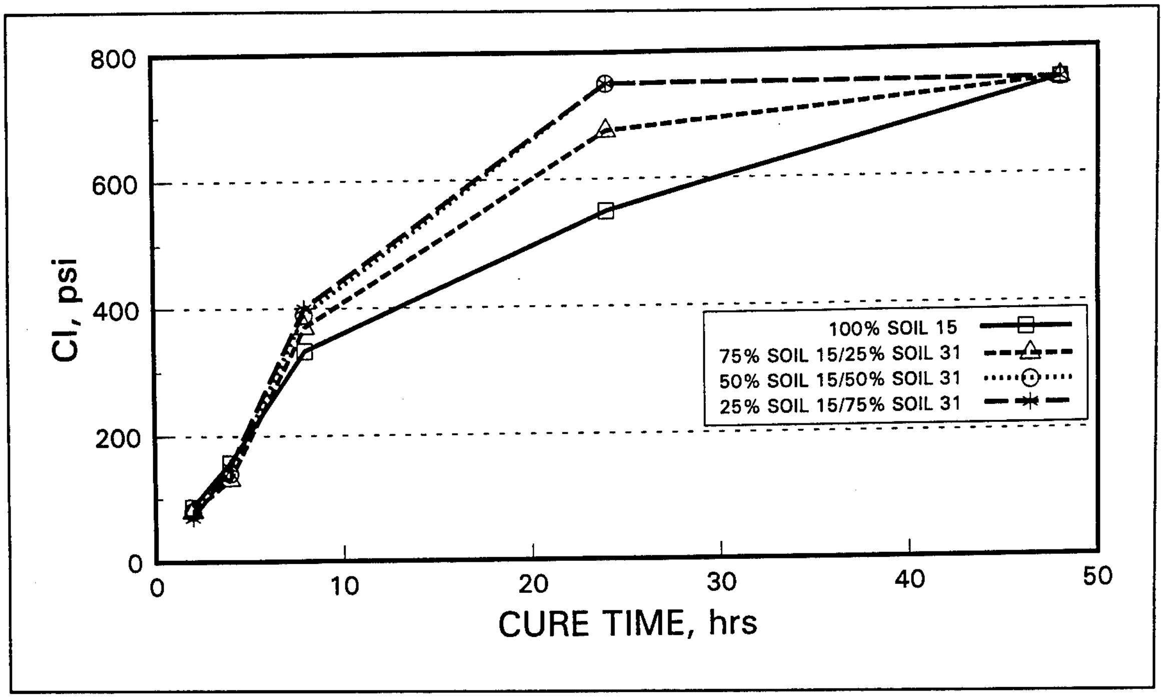

Figure 37. Average CI results of Soil 15/Soil 31 mixture

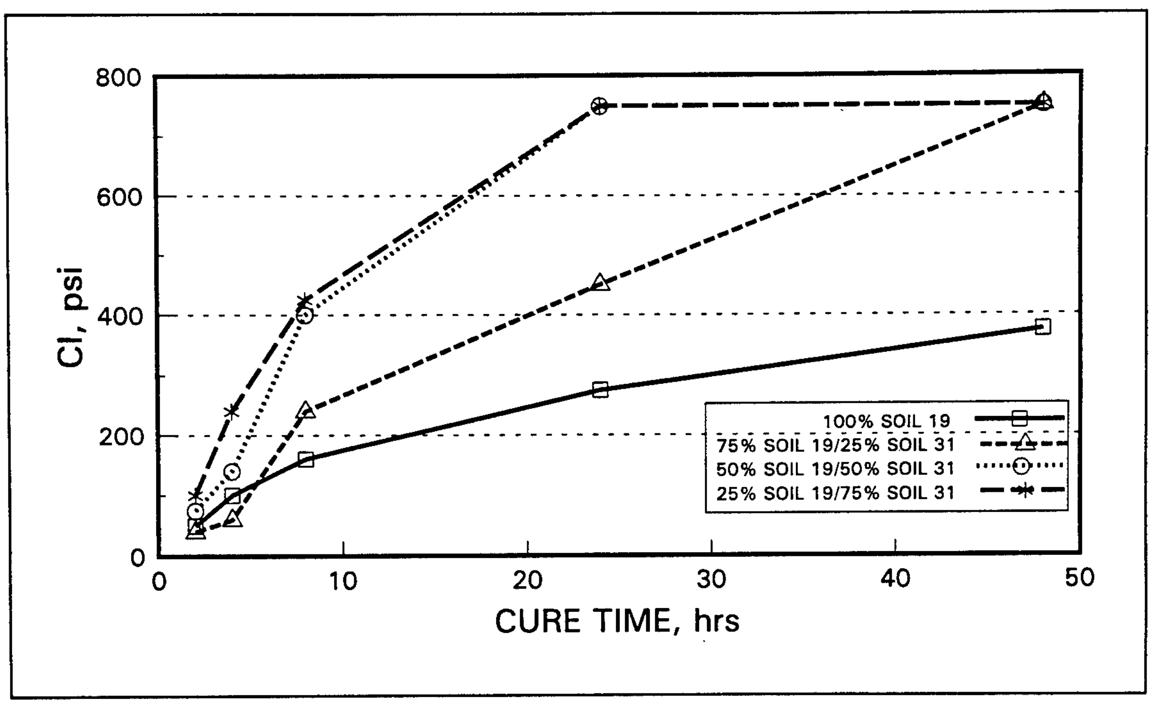

Figure 38. Average CI results for Soil 19/Soil 31 mixture

maximum CI of 750 psi after 48 hr of cure. The samples for the 50-percent Soil 19/50-percent Soil 31 and 25-percent Soil 19/75-percent Soil 31 had similar results. Both of these samples achieved the maximum CI of 750 psi after 24 hr of cure. The sample for the 75-percent Soil 19/25-percent Soil 31 achieved the maximum CI at 48 hr of cure. The 100-percent Soil 19 samples achieved a CI of 375 psi after 48 hr of cure.

The CI data for the additional study of Soils 15 and 19 closely resemble the CI data for the initial phase of the study. When Soil 15 was solidified with the 0.3/0.1 cement/fly ash binder during the initial phase of the study, the sample achieved the maximum CI of 750 psi after 8 hr of cure. When the 100-percent Soil 15 sample was solidified during the additional portion of the study using the 0.3/0.1 cement/fly ash binder, the sample achieved the maximum CI of 750 psi after 48 hr of cure. The CI for Soil 19 for the initial portion of the study using the 0.3/0.1 cement/fly ash was 425 psi after 48 hr of cure. The 100-percent Soil 19 sample for the additional portion of the study using the sample binder ratio had a CI of 375 after 48 hr of cure.

TCLP results

Table 22 presents the average results for metal for the samples tested during the additional portion of the study. All metals tested for Soil 15/31 were below the performance criteria for the study except for cadmium. Only the 100-percent Soil 15 had a cadmium concentration in the TCLP leachate below the performance criterion of 1.0 mg/ℓ. The concentration of cadmium in the 100-percent Soil 15 TCLP leachate was 0.897 mg/ℓ. The other three mixtures of Soil 15/31 were above the performance criteria for cadmium. The concentration of cadmium found in the TCLP leachate increased as the amount of Soil 15 decreased for the Soil 15/31 mixture. All of the Soil 19/31 mixtures passed the performance criteria for all metals except for the 100-percent

Table 22
Average TCLP Metal Concentrations of Additional Soil Mixtures

Soil Mixture	mg/ℓ								
	As <5.0	Ba <100.0	Be <0.004	Cd <1.0	Co na[1]	Cr <5.0	Pb <5.0	Sb <0.146	Tl na
100% Soil 15	0.005	1.66	<0.002	0.897	<0.03	0.047	0.081	<0.006	<0.004
75% 15/25% 31	<0.004	1.60	<0.002	1.19	<0.03	0.057	<0.080	<0.006	<0.004
50% 15/50% 31	<0.004	1.46	<0.002	1.45	<0.03	0.071	<0.080	<0.006	<0.004
25% 15/75% 31	<0.004	1.39	<0.002	1.80	<0.03	0.108	<0.080	<0.006	<0.004
100% Soil 19	<0.004	1.53	<0.002	1.22	<0.03	0.111	<0.080	0.048	<0.004
75% 19/25% 31	<0.004	1.57	<0.002	<0.07	<0.03	0.067	<0.080	0.015	<0.004
50% 19/50% 31	<0.004	2.31	<0.002	<0.07	<0.03	0.067	<0.080	0.005	<0.004
25% 19/75% 31	<0.004	1.72	<0.002	0.08	<0.03	0.083	<0.080	0.009	<0.004

Note: Shaded area denotes sample failed to meet performance criteria for the study.
[1] na = No criteria have been set for the compound for the TCLP test.

Soil 19 mixture. The 100-percent Soil 19 mixture had a cadmium concentration of 1.22 mg/ℓ, which failed to meet the performance criterion of 1.0 mg/ℓ for cadmium.

Table 23 presents the results of the explosive compounds for the TCLP performed on the soil mixtures that were solidified using the 0.3/0.1 cement/fly ash binder. None of the Soil 15/Soil 31 mixtures met the performance criterion of 0.07 mg/ℓ for RDX in the TCLP leachate. Even though the Soil 15/Soil 31 mixtures did not meet the criteria for RDX, it can be seen that the concentration of RDX was reduced from 22.7 mg/ℓ in the 100-percent Soil 15 to 1.20 mg/ℓ in the 25-percent Soil 15/75-percent Soil 31 sample. All of the Soil 15/Soil 31 mixtures except for the 100-percent Soil 15 sample met the performance criterion of 0.280 mg/ℓ for TNT.

All of the Soil 19/Soil 31 mixtures met the performance criteria for RDX and TNT using the 0.3/0.1 cement/fly ash binder. All of the samples were below the detection limit of 0.020 mg/ℓ for RDX and TNT except for the 100-percent Soil 19, which had a TNT concentration of 0.023 mg/ℓ.

Summary of Additional Studies

Based on the results of the initial testing of Soils 15 and 19, the Seattle District decided that additional studies were required to determine if Soils 15 and 19 could be mixed with Soil 31 and solidified to meet the performance criteria for the cleanup of the two sites. Soil 15 was mixed with Soil 31 at four weight ratios, 100-percent Soil 15/0-percent Soil 31, 75-percent Soil 15/25-percent Soil 31, 50-percent Soil 15/50-percent Soil 31, and 25-percent Soil 15/75-percent Soil 31. The same weight ratios were used for Soil 19 and Soil 31. Once the soils were mixed, they were analyzed to determine the concentration of metals and explosive compounds present in the soil.

Table 24 presents a summary of the TCLP performed on the additional soils for metals. The chemical analysis of the samples showed that all of the soil mixtures had high concentrations of cadmium, lead, and antimony. Soil 19 contained extremely high concentrations of lead ranging from 7,433 mg/kg for the 100-percent Soil 19 mixture to 2,500 mg/kg for the 25-percent Soil 19/75-percent Soil 31 mixture. Most of the metal analyses showed that as the amount of Soil 31 was added to the mixture, the concentration of metals found in the soil decreased. Table 25 presents a summary of the TCLP performed on the additional soils for explosives. The results of the explosives data for the soils indicate that Soil 15 had high concentrations of RDX and TNT. This was also observed in the intial phase of this study. Soil 19 had lower concentrations of explosives present than Soil 15, but these concentrations were close to what was observed for Soil 19 during the initial phase of the study.

Table 23
Average Explosive Compounds in Additional Soil Mixtures

Soil Mixture	mg/kg										
	HMX <35.0	RDX <0.07	TNB <1.8	DNB <0.40	TETRYL <40.0	TNT <1.8	4A-DNT na[1]	2A-DNT na	2, 6-DNT <0.024	2, 4-DNT <0.13	NB <2.0
100% Soil 15	3.47	22.7	0.457	<0.020	<0.050	0.437	0.166	0.063	<0.020	<0.020	ND[2]
75% 15/25% 31	3.40	11.7	0.193	<0.020	<0.050	<0.020	0.116	0.038	<0.020	<0.020	ND
50% 15/50% 31	3.33	9.47	0.144	<0.020	<0.050	<0.020	0.081	0.024	<0.020	<0.020	ND
25% 15/75% 31	2.52	1.20	0.039	<0.020	<0.050	<0.020	0.055	<0.020	<0.020	<0.020	ND
100% Soil 19	0.032	<0.020	0.021	<0.020	<0.050	0.023	<0.020	<0.020	<0.020	<0.020	ND
75% 19/25% 31	<0.020	<0.020	<0.020	<0.020	<0.050	<0.020	<0.020	<0.020	<0.020	<0.020	ND
50% 19/50% 31	0.024	<0.020	<0.020	<0.020	<0.050	<0.020	<0.020	<0.020	<0.020	<0.020	ND
25% 19/75% 31	<0.020	<0.020	<0.020	<0.020	<0.050	<0.020	<0.020	<0.020	<0.020	<0.020	ND

[1] na = No criteria have been set for the compound for the TCLP test.
[2] ND: Denotes that compound was not detected in sample.
Note: Shaded area denotes sample failed to meet performance criteria for the study.

Table 24
Summary of TCLP Test Results of Additional S/S Study for UMDA Soils

Soil Mixture	Cure Time days	mg/ℓ								
		As <5.0	Ba <100.0	Be <0.400	Cd <1.0	Co na[1]	Cr <5.0	Pb <5.0	Sb <0.146	Tl na
0.3 Cement/0.1 Fly Ash/0.2 Water										
100% Soil 15	2	P[2]	P	P	P	P	P	P	P	P
75% 15/25% 31	2	P	P	P	F[3]	P	P	P	P	P
50% 15/50% 31	2	P	P	P	F	P	P	P	P	P
25% 15/75% 31	2	P	P	P	F	P	P	P	P	P
100% Soil 19	2	P	P	P	F	P	P	P	P	P
75% 19/25% 31	2	P	P	P	P	P	P	P	P	P
50% 19/50% 31	2	P	P	P	P	P	P	P	P	P
25% 19/75% 31	2	P	P	P	P	P	P	P	P	P

[1] na = No criteria have been set for the compound for the TCLP test.
[2] P: Denotes that the concentration of the compound was below the performance criteria for the S/S study.
[3] F: Denotes that the concentration of the compound was above the performance criteria for the S/S study.

Table 25
Summary of TCLP Test Results of Additional S/S Study for UMDA Soils

Soil Mixture	Cure Time days	mg/ℓ								
		HMX <35.0	RDX <0.07	TNB <1.8	DNB <0.40	TNT <0.280	2, 4-DNT <0.13	2, 6-DNT <0.024	NB <2.0	TETRYL <40.0
0.3 Cement/0.1 Fly Ash/0.2 Water										
100% Soil 15	2	P[1]	F[2]	P	P	F	P	P	P	P
75% 15/25% 31	2	P	F	P	P	P	P	P	P	P
50% 15/50% 31	2	P	F	P	P	P	P	P	P	P
25% 15/75% 31	2	P	F	P	P	P	P	P	P	P
100% Soil 19	2	P	P	P	P	P	P	P	P	P
75% 19/25% 31	2	P	P	P	P	P	P	P	P	P
50% 19/50% 31	2	P	P	P	P	P	P	P	P	P
25% 19/75% 31	2	P	P	P	P	P	P	P	P	P

[1] P: Denotes that the concentration of the compound was below the performance criteria for the S/S study.
[2] F: Denotes that the concentration of the compound was above the performance criteria for the S/S study.

The results of the TCLP performed on the untreated soils indicate that none of the metals were above the performance criteria for the study. The results of the TCLP for Soil 19 show that lead and antimony failed to meet the performance criteria for all of the samples. Cadmium failed to meet the performance criteria for all of the samples except for the 25-percent Soil 19/ 75-percent Soil 31 sample. The explosive data for the TCLP for Soil 15 show that all samples failed for RDX and TNT. This was expected due to the extremely high concentrations of these compounds found in the soil. The results of the TCLP for Soil 19 show that only the 100-percent Soil 19 and 75-percent Soil 19/25-percent Soil 31 failed to meet the performance criteria for RDX. All samples for Soil 19 except for the 25-percent Soil 19/75-percent Soil 31 failed to meet the performance criteria for TNT.

The soils were solidified using only one binder of 0.3 cement/0.1 fly ash by weight. In order for the hydration of the binder to occur, water was added to the soil at a ratio of 0.2 by weight. The samples were cured in an environmental chamber at 23 °C and 98-percent relative humidity for 48 hr before testing of the samples began. Cone Index was performed on the samples during the cure time to determine the set time of the soil/binder/water mixture.

The results of the CI for Soil 15 show that all mixtures achieved the maximum CI of 750 psi after 48 hr of cure. As expected, the lower ratios of Soil 15 used with Soil 31 achieved the maximum CI faster than did the higher ratios of Soil 15 used with Soil 31. This was expected due to the higher concentrations of explosive compounds found in the soil when more of Soil 15 was used to mix with Soil 31. The CI for Soil 19 shows that all of the soil mixtures achieved the maximum CI of 750 psi except for the 100-percent Soil 19 mixture. The 100-percent Soil 19 mixture only achieved a CI of 380 psi after 48 hr of cure.

After 48 hr of cure, the samples were subjected to the TCLP test to determine the leachability of the contaminants from the solidified sample. The results of the metals analyses for Soil 15 show that only the 100-percent Soil 15 sample met all of the performance criteria for the metal contaminants. All of the other mixtures of Soil 15 failed to meet the performance criteria of 1.0 mg/ℓ of cadmium in the TCLP leachate. The metals analyses of the TCLP leachate for the solidified Soil 19 samples show that all samples except for the 100-percent Soil 19 met the performance criteria for metals in the TCLP leachate. The 100-percent Soil 19 sample failed to meet the performance criteria of 1.0 mg/ℓ of cadmium in the TCLP leachate.

The results of the explosives for the TCLP for Soil 15 show that all samples failed to meet the performance criterion of 0.07 mg/ℓ of RDX in the TCLP leachate. While all samples failed the TCLP for RDX, only the 100-percent Soil 15 sample failed to meet the performance criterion of 0.280 mg/ℓ of TNT in the TCLP leachate. The soil mixtures using Soil 19 met the performance criteria for all explosive compounds for the TCLP.

Based on the results of the TCLP for the solidified samples, none of the mixtures using Soil 15 and Soil 31 met the performance criteria for the study. All of the samples failed to meet the performance criteria for RDX, and three of the samples failed to meet the performance criteria for cadmium in the TCLP leahcate. The mixtures using Soils 19 and 31 met the performance criteria for metals and explosives in the TCLP leahcate except for the 100-percent Soil 19 sample, which failed to meet the criteria for cadmium.

6 Addition of Granular Activated Carbon to Soil 15

Granular activated carbon has been shown to treat groundwater that is contaminated with explosive compounds. Since the soils found at the UMDA have a high sand content, it was surmised that the explosive compounds (RDX and TNT) were not tightly bound to the soil particles. During the S/S of UMDA soils, it is possible that explosives are solubilized when hydrated during the soil/water/binder mixing process. In an attempt to capture solubilized explosives, activated carbon was added to the soil/water slurry and mixed for 5 min before adding the 0.3/0.1 cement/fly ash binder. If the explosive compounds were solubilized in the water phase, this may allow the carbon to adsorb the explosive compounds and then possibly be encapsulated with the addition of the binder.

Three of the mixtures of Soils 15 and 31 that were used for the Phase II study were used for this portion of the test. These soils were the 100-percent Soil 15, 75-percent Soil 15/25-percent Soil 31, and 50-percent Soil 15/50-percent Soil 31. Table 26 presents the bulk cadmium and lead concentrations for the Soil 15/31 mixtures used for the carbon addition study. Since cadmium and lead were the only metals to fail to meet the performance criteria in the previous studies, only these two metals were analyzed for the carbon addition study.

Table 26
Average Metal Concentrations of Phase III Soils

Soil Mixtures	Cadmium, mg/kg	Lead, mg/kg
100% Soil 15	45.3	500
75% Soil 15/25% Soil 31	27.3	220
50% Soil 15/50% Soil 31	22.0	230

Table 27 presents the bulk HMX, RDX, TNB, and TNT concentrations for the Soil 15/31 mixtures used for the Phase III study. Only the compounds RDX, HMX, TNB, and TNT were analyzed for this portion of the study.

Table 27
Average Explosive Concentrations of Phase III Soils

Soil Mixtures	mg/kg			
	HMX	RDX	TNB	TNT
100% Soil 15	609	3,867	39.5	5,037
75% Soil 15/25% Soil 31	493	3,056	31.0	4,510
50% Soil 15/50% Soil 31	351	2,070	20.1	2,870

Table 28 presents the average TCLP metals concentrations for the untreated Soil 15/31 mixtures. Table 28 shows that all of the soil mixtures for Soil 15/31 met the TCLP and performance goals for the study for the untreated soil.

Table 28
Average TCLP Metal Concentrations for Untreated Soil 15 Mixtures

Soil Mixtures	Cadmium, mg/ℓ[1]	Lead, mg/ℓ[2]
100% Soil 15	0.757	0.737
75% Soil 15/25% Soil 31	0.230	0.209
50% Soil 15/50% Soil 31	0.281	0.178

[1] Criterion for cadmium was 1.0 mg/ℓ.
[2] Criterion for lead was 5.0 mg/ℓ.

Table 29 presents the TCLP results performed on the untreated Soil 15/31 mixtures for the explosive compounds. Table 29 shows that the RDX and TNT failed to meet the performance goals for the study before carbon treatment.

Table 29
Average TCLP Explosive Concentrations for Untreated Soil 15/31 Mixtures

Soil Mixtures	mg/ℓ			
	HMX[1]	RDX[2]	TNB[3]	TNT[4]
100% Soil 15	6.31	33.8	0.450	30.3
75% Soil 15/25% Soil 31	5.10	32.4	0.246	22.5
50% Soil 15/50% Soil 31	4.63	30.8	0.223	24.7

[1] Criterion for HMX was 35.0 mg/ℓ.
[2] Criterion for RDX was 0.07 mg/ℓ.
[3] Criterion for TNB was 1.8 mg/ℓ.
[4] Criterion for TNT was 0.280 mg/ℓ.

Carbon treatment of the Soil 15/31 mixtures involved mixing the soil with a 0.2 water ratio for 5 min. At the end of the 5 min of mixing, varying ratios of carbon were added to soil/water mixtures. Carbon-to-soil ratios of 0.01, 0.05, and 0.10 were evaluated for this study. The soil/water/carbon slurry was mixed for 5 additional min. After mixing, the 0.3/0.1 cement/ fly ash binder was added to the slurry and mixed for 5 additional min. Upon completion of the mixing, the soil was placed into molds and allowed to cure for 48 hr at 23 °C and 98-percent relative humidity.

At the end of the 48-hr cure time, the samples were subjected to the TCLP for leaching evaluation. Table 30 presents the average metals concentrations found in the TCLP leachate. All samples tested using the carbon addition passed the TCLP and performance criterion of 1.0 mg/ℓ for cadmium and 5.0 mg/ℓ for lead.

Table 30
Average Metals Concentrations in TCLP for Phase III Soils

Soil Mixtures	Cadmium, mg/ℓ	Lead, mg/ℓ
0.01 Carbon		
100% Soil 15	<0.010	0.056
75% Soil 15/25% Soil 31	<0.010	<0.050
50% Soil 15/50% Soil 31	<0.010	<0.050
0.05 Carbon		
100% Soil 15	<0.010	<0.050
75% Soil 15/25% Soil 31	<0.010	<0.050
50% Soil 15/50% Soil 31	<0.010	<0.050
0.10 Carbon		
100% Soil 15	<0.010	<0.050
75% Soil 15/25% Soil 31	<0.010	<0.050
50% Soil 15/50% Soil 31	<0.010	<0.050

Table 31 presents the TCLP results of leachate analysis for the explosive compounds for the carbon/soil/binder mixtures. The addition of carbon to the 100-percent Soil 15 shows all explosive compound concentrations were below the detection limits of 0.02 mg/ℓ, meeting the performance goals for the study. However, the 75-percent Soil 15/25-percent Soil 31 results were not as promising as the 100-percent Soil 15 results. Only the mixture using the 0.1 carbon-to-soil ratio for the 75-percent Soil 15/25-percent Soil 31 met the performance criteria for RDX. The 0.01 carbon addition failed to meet the performance criteria for RDX and TNT, while the 0.05 carbon addition only failed to meet

Table 31
Average TCLP Explosives Concentrations in Phase III Soils

Soil Mixtures	mg/ℓ HMX	RDX	TNB	TNT
0.01 Carbon				
100% Soil 15	<0.02	<0.02	<0.02	<0.02
75% Soil 15/25% Soil 31	3.12	18.1	0.135	3.55
50% Soil 15/50% Soil 31	0.339	1.71	<0.02	<0.02
0.05 Carbon				
100% Soil 15	<0.02	<0.02	<0.02	<0.02
75% Soil 15/25% Soil 31	<0.02	0.217	<0.02	<0.02
50% Soil 15/50% Soil 31	<0.02	0.018	<0.02	<0.02
0.10 Carbon				
100% Soil 15	<0.02	<0.02	<0.02	<0.02
75% Soil 15/25% Soil 31	<0.02	0.023	<0.02	<0.02
50% Soil 15/50% Soil 31	0.04	2.26	<0.02	<0.02

the criteria for RDX for the 75-percent Soil 15/25-percent Soil 31 mixture. The 50-percent Soil 15/50-percent Soil 31 mixture with the addition of carbon met the performance criteria for TNT for all mixtures. The performance goal for RDX was met only for the 0.05 carbon-to-soil mixture for the 50-percent Soil 15/50-percent Soil 31 mixture. It should be noted that the two replicates for the 0.10 carbon-soil ratio for the 50-percent Soil 15/50-percent Soil 31 mixture showed varying RDX concentrations. Replicate A contained 4.5 mg/ℓ of RDX in the TCLP leachate, while Replicate B was below the detection limit of 0.02 mg/ℓ for RDX.

The research conducted on the use of carbon for treating groundwater contaminated with explosives has shown that equilibrium is reached between the carbon and explosive compound. Equilibrium has been reached when the explosive concentration in the aqueous phase is no longer decreasing. The initial study for Phase III only allowed the carbon/soil/water slurry to mix for 5 min before the addition of the binder. Since the Phase III study showed promise for the successful treatment of the metals and explosive compounds in the UMDA soil, it was decided by personnel at WES to repeat the study using a longer contact time between the carbon/soil/water slurry. The same soil mixtures were used for this portion of the testing with the addition of a 12-percent Soil 15/88-percent Soil 31 mixture. This mixture was requested by personnel at the Seattle District to achieve an RDX concentration of approximately 250 mg/kg in the soil.

Additional soil had to be mixed to perform this portion of the study. Table 32 presents the bulk RDX and TNT analyses of the soils used for this portion of the study. It should be noted that only RDX and TNT were analyzed for this phase of the study since the previous carbon study showed treatment for the cadmium and lead contaminants.

Table 32
Average Concentration of Explosives in Soil 15/31 Mixtures

Soil Mixtures	RDX, mg/kg	TNT, mg/kg
100% Soil 15	4,405	4,140
75% Soil 15/25% Soil 31	2,450	3,010
50% Soil 15/50% Soil 31	1,790	2,355
12% Soil 15/88% Soil 31	217	246

Once the soil mixtures were characterized for RDX and TNT, they were treated using varying dosages of carbon and a binder ratio of 0.3/0.1 cement/fly ash. Carbon ratios used for this portion of the study were 0.10, 0.15, 0.20, and 0.25. The same water ratio of 0.2 was used for the preparation of the soil slurry mixture. After the soil/water slurry was mixed for 5 min, the carbon was added to the mixture. The carbon/soil/water mixture was allowed to mix for 10 min before the addition of the cement/fly ash binder.

Table 33 presents the average results of the analysis of the TCLP leachate for RDX and TNT. It should be noted that the TCLP was performed in triplicate for this study due to the fact that some of the results of the previous study were varying between duplicates. It can be seen from Table 32 that TNT was treated below the detection limit of 0.02 mg/ℓ for all samples tested. RDX was treated below the performance criterion of 0.07 mg/ℓ for all samples except for the 100-percent Soil 15 sample using the 0.10 carbon addition.

The data from Table 33 show that as more carbon is added to the soil/water slurry, the concentration of RDX in the TCLP leachate is reduced. Table 33 also indicates that a more effective treatment is achieved by allowing the carbon to mix with the soil/water slurry for 10 min rather than 5 min as was previously used in the first carbon study.

The study using carbon as an additive for S/S of the UMDA Soil 15 indicates that the performance goals for the overall treatment of the soils can be achieved. Mixtures of Soils 15 and 31 used for this study had average RDX and TNT concentrations ranging from approximately 4,405 to 212 mg/kg for RDX and 4,140 to 246 mg/kg for TNT. Varying ratios of carbon were added to the soil/water slurry and mixed for 5 and 10 min before the addition of the 0.3/0.1 cement/fly ash binder. While some of the samples used for the 5-min mixing time showed treatment of RDX and TNT, not all of the samples were treated below the performance goals for the study. The ratios evaluated in the

Table 33
Average Results of TCLP for Explosive Compounds for Treated Soil 15 Mixtures

Soil Mixture	Carbon Addition	RDX, mg/ℓ	TNT, mg/ℓ
100% Soil 15	0.10	0.351	<0.02
	0.15	0.057	<0.02
	0.20	0.017	<0.02
	0.25	0.013	<0.02
75% Soil 15/25% Soil 31	0.10	0.042	<0.02
	0.15	0.014	<0.02
	0.20	0.008	<0.02
	0.25	<0.020	<0.02
50% Soil 15/50% Soil 31	0.10	0.013	<0.02
	0.15	<0.020	<0.02
	0.20	<0.020	<0.02
	0.25	<0.020	<0.02
12% Soil 15/88% Soil 31	0.10	<0.020	<0.02
	0.15	<0.020	<0.02
	0.20	<0.020	<0.02
	0.25	<0.020	<0.02

Note: All values reported below 0.020 are reported as J values.

first carbon study were 0.01, 0.05, and 0.10 based on the weight of the soil used for the sample. The low ratios of carbon used for the 5-min mixing did indicate that the metals cadmium and lead found in the Soil 15/31 mixtures were below the TCLP and performance criteria of 1.0 mg/ℓ for cadmium and 5.0 mg/ℓ for lead.

The samples used for the 10-min mixing time for the carbon and soil/water slurry used higher ratios of carbon than the samples prepared using a 5-min mix time for the carbon and soil/water slurry. Carbon ratios used for the 10-min mixing time were 0.10, 0.15, 0.20, and 0.25 based on the weight of the soil used for the sample. The samples that were prepared using carbon and mixed for 10 min showed effective treatment of all samples tested for RDX and TNT except for the 100-percent Soil 15 using a 0.1 carbon ratio addition. This sample did not effectively treat RDX below the performance goal of 0.07 mg/ℓ for RDX for the study. Based on the data for the addition of carbon, the UMDA Soil 15 that is contaminated with metals and explosives

can be effectively treated to meet the performance goals for metals and explosive compounds.

Based on the results of the TCLP for the solidified samples, none of the mixtures using Soil 15 and Soil 31 met the performance criteria for the study. All of the samples failed to meet the performance criteria for RDX, and three of the samples failed to meet the performance criteria for cadmium in the TCLP leachate. The mixtures using Soil 19 and Soil 31 met the performance criteria for metals and explosives in the TCLP leachate except for the 100-percent Soil 19 sample, which failed to meet the criteria for cadmium.

7 Recommendations

Phases I and II

The recommendations for the BSRs to be used for the treatment of the four soils are based on the performance of the BSRs for all of the physical tests and the TCLP leach test. The BSRs recommended in this section were the BSRs that performed the best during this treatment study.

The BSR of 0.3/0.1 cement/fly ash performed the best overall for Soil 2236. This BSR did not indicate the presence of free liquid during the paint filter test and did not produce bleed water during the 14-day cure time. This sample had a slump of 4 in. immediately after mixing, but showed that it achieved a CI of 750 psi after 8 hr of cure. The UCS for the 0.3/0.1 BSR was 1,900 lb/ft^3. This UCS remained relatively constant for the UCS test. The 0.3/0.1 BSR had a bulk density of 129 lb/ft^3 and a volume increase of 52.4 percent. The 0.3/0.1 BSR met the TCLP and performance criteria for both the 2- and 14-day TCLP for cadmium, chromium, and lead. Explosive compounds were not of concern for Soil 2236.

The optimal BSRs for Soil 15 based on the first evaluation of Soil 15 were 0.3/0.1 and 0.3/0.3 cement/fly ash. Neither BSR showed the presence of free liquid during the paint filter test and did not produce bleed water during the 14-day cure time. The 0.3/0.1 BSR had a slump of 1 in. immediately after mixing, while the 0.3/0.3 BSR did not slump during the test. Both BSRs had a CI of 750 psi after 8 hr of cure. The UCS determinations showed that both BSRs achieved their maximum strength at 10 days of cure and slightly decreased after this time. The 0.3/0.1 BSR had a bulk density of 130 lb/ft^3 with a volume increase of 40.7 percent. The 0.3/0.3 BSR had a bulk density of 119 lb/ft^3 with a volume increase of 78 percent. Both BSRs met the TCLP and performance criteria for metals in the TCLP leachate. The 0.3/0.1 BSR met the performance criteria for the 2-day TCLP for explosives but failed the 14-day TCLP for RDX and TNT. The concentration of RDX in the 14-day TCLP leachate for the 0.3/0.1 BSR was 0.70 mg/ℓ, ten times greater than the performance criterion of 0.070 mg/ℓ. TNT was slightly greater than the performance criterion of 0.280 mg/ℓ for the 0.3/0.1 BSR. The 0.3/0.3 BSR met the performance criteria for explosives for the 2-day TCLP, but failed to meet the performance criteria for the 14-day TCLP. The 0.3/0.3 BSR failed to meet

the performance criterion for RDX by 0.37 mg/ℓ. Both of these BSRs performed well for the physical portion of the testing and for the treatment of the metal contaminants. The treatment of the explosive compounds did not meet the performance criteria for either of the two BSRs. Because the performance criteria for the explosive compounds was not met for the 14-day TCLP leachate, no sample can be recommended for use from the results of this study unless the performance criteria are relaxed.

As with Soil 15, the TCLP results for Soil 19 based on the initial evaluation of Soil 19 showed that none of the BSRs evaluated met all the performance criteria for metals and explosives. The two BSRs that performed better for Soil 19 were the 0.5 cement BSR and the 0.3/0.1 cement/fly ash BSR. Both BSRs passed the paint filter test and did not indicate the presence of bleed water during the 14-day test period. The 0.5 BSR had a slump of 1 in. immediately after mixing, while the 0.3/0.1 BSR had a slump of 2 in. Both BSRs had a CI of 420 psi after 48 hr of cure. Both BSRs achieved the highest UCS at 10 days of cure and decreased after this time. The 0.5 BSR had a bulk density of 122 lb/ft^3, while the 0.3/0.1 had a bulk density of 119 lb/ft^3. Both BSRs had a volume increase of approximately 61 percent. The 0.5 cement BSR met the TCLP and performance criteria for metals for both the 2- and 14-day TCLP. The 0.3/0.1 cement/fly ash BSR met the 2-day TCLP and performance criteria for metals, but failed the 14-day TCLP for cadmium. The concentration of cadmium in the 14-day TCLP leachate for the 0.3/0.1 BSR was 1.57 mg/ℓ. The 0.5 BSR met the performance criteria for the 2-day TCLP for explosives, but the Replicate B sample failed for the 14-day TCLP for RDX and TNT. The concentration of RDX and TNT in the 14-day TCLP leachate for the 0.5 BSR was above the performance criteria by 0.012 mg/ℓ RDX and 0.40 mg/ℓ TNT. The 0.3/0.1 BSR was the only BSR for Soil 19 to meet the explosives performance criteria for both the 2- and 14-day TCLP. Because no BSR met all of the current performance criteria specified for this study, no formulation can be recommended for the treatment of Soil 19.

The 0.1/0.3 cement/fly ash BSR was chosen to perform the best for Soil 31. This BSR passed the paint filter test and did not indicate the presence of bleed water during the 14-day cure time. The 0.1/0.3 BSR had a slump of 1 1/2 in. immediately after mixing was complete. The 0.1/0.3 BSR achieved the maximum CI of 750 psi after 48 hr of cure and had a UCS of 1,600 lb/ft^3 that remained steady for the 14-day test time. The 0.1/0.3 cement/ fly ash BSR had a bulk density of 121 lb/ft$_3$ and a volume increase of 42 percent. This BSR met the performance criteria for metals and explosives for both the 2- and 14-day TCLP.

The second phase of the study showed that by mixing Soil 19 with Soil 31, the performance criteria for the cleanup of the site can be achieved. Based on the results of the study, it is recommended that a mixture of soils be made to achieve the same concentrations of contaminants that were used in this study. The mixing of Soil 15 with Soil 31 did not show effective treatment of cadmium and RDX. As the amount of Soil 15 was decreased, the amount of cadmium leaching from the sample during the TCLP increased. On the other

hand, as the amount of Soil 15 was decreased, the amount of RDX in the TCLP leachate decreased. Additional studies could be performed to determine if the addition of granular activated carbon or organophilic clay could be added to the soil to absorb the explosives leaching from the sample. This could also aid in the amount of cadmium leached from the sample if the explosive compounds are interfering with the solidification process.

Phase III

The recommendations for the BSR (0.3/0.1 cement/fly ash) and carbon ratios to be used for the treatment of soil mixtures consisting of Soils 15/31 and 19/31 are based on the performance of the BSR and carbon ratios for the TCLP leach test. The BSR recommended in this section is the 0.3/0.1 cement/fly ash binder that performed the best for the Phase I evaluation of the four soils.

Carbon ratios of 0.01, 0.05, and 0.10 were used in the solidification of Soil 15/31 mixtures. These ratios of carbon were allowed to mix with the soil/water slurry for 5 min before the addition of the binder. Once the binder was added, the samples were mixed and placed in molds and cured for 48 hr at 23 °C and 98-percent relative humidity. After the 48-hr cure time, the samples were subjected to the TCLP to evaluate the leaching potential of cadmium, lead, and explosive compounds. The data for the carbon ratios showed that cadmium and lead were treated below the detection limits for the two metals. The data for the explosive compounds (particularly RDX and TNT) showed treatment for all soil and carbon ratios for TNT except for the 75-percent Soil 15/25-percent Soil 31 with the 0.01 carbon addition. RDX was not treated for all soil and carbon ratios. The data for the carbon additions indicated that the results of the study for RDX were variable and no conclusions could be made for the treatment efficiency using carbon. It was noted that for most soil/carbon mixtures that as more carbon was added to the soil/water slurry, the concentration of RDX was decreased.

Based on the initial carbon treatment study, a second study was performed using carbon ratios of 0.1, 0.15, 0.2, and 0.25. These carbon ratios were allowed to mix with the soil/water slurry for 10 min instead of the 5 min used in the initial carbon study. The same Soil 15/31 mixtures were used for this study along with a 12-percent Soil 15/88-percent Soil 31 mixture. These samples were solidified and allowed to cure for 24 hr before being subjected to the TCLP test. All of the soil/carbon mixtures showed that the concentration of TNT in the TCLP leachate was below the detection limit of 0.02 mg/ℓ. This indicated that treatment of the soil using carbon was successful for TNT. The concentration of RDX in the TCLP leachate showed that the performance goal of 0.07 mg/ℓ was achieved for all soil/carbon mixtures except for the 100-percent Soil 15 with the 0.1 carbon addition. The concentration of RDX in the TCLP leachate decreased as the amount of carbon added to the soil/water slurry increased.

The addition of carbon to the Soil 15/31 mixtures shows that as the amount of carbon added to the mixture increases, the concentration of RDX in the TCLP leachate decreases. Also, with the addition of the carbon to the soil/water slurry, the time allowed for the carbon to mix with the soil/water shows that an increase in time helps to reduce the concentration of RDX in the TCLP leachate. Based on the study conducted using carbon as an additive for S/S, the concentrations of cadmium, lead, RDX, and TNT can meet the performance criteria for the treatment of the soil.

8 Conclusions

A laboratory study was conducted to investigate the effects of two S/S processes on four contaminated soils from the Umatilla Army Depot. Physical and chemical tests were performed on the solidified/stabilized specimens. Based on the results of these tests, the following conclusions can be made:

a. BSRs evaluated produced materials with UCSs above the 50-psi criterion except for the 0.1/0.1 cement/fly ash BSR for Soil 19.

b. Water must be added to the soils for hydration of the binders to develop strength.

c. The BSRs of 0.1 and 0.3 cement and 0.1/0.1 cement/fly ash failed the paint filter test because of the presence of free liquid immediately after mixing.

d. The S/S processing of the soil was effective in reducing the mobility of metal contaminants below the performance criteria for the four Umatilla soils.

e. The presence of explosive compounds in Soils 15 and 19 appear to retard to the set of some of the BSRs evaluated.

f. S/S processing of Soils 15 and 19 did not reduce the leachability of the explosive contaminants below the performance criteria established for remediation of these soils.

g. S/S processing of Soils 2236 and 31 met the performance criteria for metals and explosives for the remediation of these soils.

An additional study was performed on Soils 15 and 19 to determine if mixing these soils with Soil 31 could aid in the soils meeting the performance criteria for the study. The results of the additional studies showed the following:

h. Mixing Soils 15 and 19 with Soil 31 decreased the amount of contaminants present in the soil as more of Soil 31 was added to Soils 15 and 19.

i. All of the samples evaluated during the additional phase of the study achieved the maximum CI of 750 psi except for the 100-percent Soil 19 sample.

j. The results of the TCLP for metals on the solidified samples show that all samples for Soil 15 failed to meet the performance criteria for cadmium except for the 100-percent Soil 15 sample.

k. The results of the TCLP for metals on the solidified samples show that all samples for Soil 19 met the performance criteria except for the 100-percent Soil 19 sample, which failed for cadmium.

l. The results of the TCLP for explosives for Soil 15 for the solidified samples show that all samples failed to meet the performance criteria for RDX.

m. The results of the TCLP for explosives for Soil 19 for the solidified samples show that all samples met the performance criteria for the explosive compounds.

n. The mixing of Soils 15 and 31 does not aid Soil 15 in meeting the performance criteria for the cleanup of the site.

o. The mixing of Soils 19 and 31 does aid in Soil 19 meeting the performance criteria for the cleanup of the site.

A study was conducted to determine if the addition of activated carbon to the S/S mixture could help to meet the performance criteria for cadmium, lead, RDX, and TNT. The results of this study indicate the following:

p. The addition of carbon to mixtures of Soil 15/31 can help to reduce the concentration of lead and cadmium below the TCLP and performance criteria for the treatment of the soils.

q. The addition of carbon to the mixtures of Soil 15/31 can reduce the concentration of RDX and TNT below the performance criteria for the treatment of the soils.

r. As the amount of carbon added to the soil/water slurry increases, the concentration of RDX in the TCLP leachate decreases.

s. An increase in the time allowed for the mixing of the carbon/soil/water increases the effectiveness of the carbon to reduce the leaching of the RDX in the TCLP.

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Appendix A
Results of Physical and Chemical Tests Performed on Untreated Umatilla Army Depot Soils

Table A1
Results of Physical Tests Conducted on Untreated Umatilla Soils

Soil	Replicate	Moisture Content %	Bulk Density lb/ft^3	Proctor Density lb/ft^3	UCS psi	Specific Gravity	Cone Index psi
2236	A	6.0	114	139.3	0	2.69	145
2236	B	6.0	120	139.7	0	2.67	145
15	A	5.3	77	129.6	0	2.74	200
15	B	5.1	72	130.3	0	2.73	200
19	A	8.3	93	135.9	0	2.78	175
19	B	8.0	94	133.6	0	2.76	190
31	A	6.0	102	125.5	0	2.69	100
31	B	6.0	101	126.8	0	2.70	90

Table A2
Results of Grain-Size Analysis of Untreated Umatilla Army Depot Soils

Weight, g	Sieve Size or Number	Opening mm	Percent Finer	Percent Coarser
Soil 2236				
0.0	1/2 in.	12.500	100.0	0.0
21.8	3/8 in.	9.500	99.0	1.0
65.1	No. 3	6.350	95.9	4.1
51.7	No. 4	4.750	93.5	6.5
3.5	No. 6	3.350	89.6	10.4
7.7	No. 10	2.000	85.0	15.0
10.8	No. 16	1.180	81.5	18.5
13.7	No. 20	0.850	78.3	21.7
18.3	No. 30	0.600	73.2	26.8
29.3	No. 40	0.425	61.0	39.0
42.5	No. 50	0.300	46.3	53.7
53.4	No. 70	0.212	34.2	65.8
59.9	No. 100	0.150	27.0	73.0
64.5	No. 140	0.106	21.9	78.1
69.3	No. 200	0.075	16.6	83.4
Percent Gravel = 6.5; Percent Sand = 77.0; Percent Fines = 16.6.				
Soil 15				
0.0	1/2 in.	12.500	100.0	0.0
9.5	3/8 in.	9.500	99.3	0.7
11.2	No. 3	6.350	98.6	1.4
11.5	No. 4	4.750	97.8	2.2
0.9	No. 6	3.350	96.3	3.7
2.2	No. 10	2.000	94.1	5.9
3.6	No. 16	1.180	91.8	8.2
4.6	No. 20	0.850	90.2	9.8
5.8	No. 30	0.600	88.2	11.8
8.9	No. 40	0.425	83.1	16.9
14.2	No. 50	0.300	74.3	25.7

(Sheet 1 of 3)

Table A2 (Continued)

Weight, g	Sieve Size or Number	Opening mm	Percent Finer	Percent Coarser
Soil 15 (Continued)				
23.0	No. 70	0.212	59.7	40.3
32.8	No. 100	0.150	43.5	56.5
40.7	No. 140	0.106	30.4	69.6
48.2	No. 200	0.075	18.0	82.0
Percent Gravel = 2.2; Percent Sand = 79.8; Percent Fines = 18.0.				
Soil 19				
7.3	1/2 in.	12.500	99.5	0.5
23.9	3/8 in.	9.500	97.8	2.2
32.1	No. 3	6.350	95.6	4.4
43.7	No. 4	4.750	92.5	7.5
2.0	No. 6	3.350	90.2	9.8
5.3	No. 10	2.000	86.4	13.6
8.7	No. 16	1.180	82.5	17.5
11.8	No. 20	0.850	79.0	21.0
15.3	No. 30	0.600	75.0	25.0
20.8	No. 40	0.425	68.7	31.3
27.5	No. 50	0.300	61.0	39.0
37.1	No. 70	0.212	50.0	50.0
47.4	No. 100	0.150	38.2	61.8
55.8	No. 140	0.106	28.5	71.5
64.0	No. 200	0.075	19.1	80.9
Percent Gravel = 7.5; Percent Sand = 73.4; Percent Fines = 19.1.				
Soil 31				
0.0	1/2 in.	12.500	100.0	0.0
41.0	3/8 in.	9.500	97.6	2.4
58.4	No. 3	6.350	94.1	5.9
28.0	No. 4	4.750	92.4	7.6
1.0	No. 6	3.350	91.1	8.9
2.8	No. 10	2.000	88.9	11.1

(Sheet 2 of 3)

Table A2 (Concluded)

Soil 31 (Continued)				
Weight, g	**Sieve Size or Number**	**Opening mm**	**Percent Finer**	**Percent Coarser**
4.7	No. 16	1.180	86.6	13.4
7.2	No. 20	0.850	83.5	16.5
11.0	No. 30	0.600	78.7	21.3
18.5	No. 40	0.425	69.4	30.6
28.7	No. 50	0.300	56.8	43.2
43.3	No. 70	0.212	38.7	61.3
54.4	No. 100	0.150	24.9	75.1
60.9	No. 140	0.106	16.9	83.1
65.7	No. 200	0.075	10.9	89.1
Percent Gravel = 7.6; Percent Sand = 81.5; Percent Fines = 10.9				
				(Sheet 3 of 3)

Table A3
Results for Metals for Bulk Chemistry for Untreated Umatilla Army Depot Soils

		mg/kg								
Soil	**Replicate**	**As**	**Ba**	**Be**	**Cd**	**Co**	**Cr**	**Pb**	**Sb**	**Tl**
2236	A	NA	NA	NA	1,200	NA	200	700	NA	NA
2236	B	NA	NA	NA	1,200	NA	170	600	NA	NA
15	A	2.5	210	0.18	31	5.8	38	180	3.1	<0.20
15	B	2.4	240	0.19	29	5.4	35	170	3.6	<0.20
19	A	15.0	1,300	NA	55	NA	13	3,600	12.0	NA
19	B	4.8	1,300	NA	68	NA	13	3,300	93.0	NA
31	A	NA	NA	NA	0.31	NA	6.6	43	NA	NA
31	B	NA	NA	NA	0.29	NA	8.1	16	NA	NA

Table A4
Results for Explosives for Bulk Chemistry for Untreated Umatilla Army Depot Soils

Soil	Replicate	mg/ℓ									
		HMX	RDX	TNB	DNB	TETRYL	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT
2236	A	<2.20	0.08	0.105	<0.25	<0.65	<0.65	<0.25	<0.25	<0.26	<0.25
2236	B	<2.20	0.115	0.060	<0.25	<0.65	<0.65	<0.25	<0.25	<0.26	<0.25
15	A	447	2,870	52.5	<0.25	<0.65	3,990	<0.25	<0.25	<0.26	<0.25
15	B	470	3,030	48.0	<0.25	<0.65	3,770	<0.25	<0.25	<0.26	0.26
19	A	5.8	13.1	12.9	<0.25	<0.65	109	<0.25	0.335	<0.26	0.02
19	B	7.3	15.1	13.1	<0.25	<0.65	63.1	<0.25	0.298	<0.26	0.135
31	A	<2.20	0.11	<0.25	<0.25	<0.65	0.12	0.115	<0.25	<0.26	<0.25
31	B	0.125	0.36	<0.25	<0.25	<0.65	0.836	0.135	<0.25	<0.26	<0.25

Table A5
Results for Explosives for TCLP for Untreated Umatilla Army Depot Soils

Soil	Replicate	mg/ℓ									
		HMX	RDX	TNB	DNB	TETRYL	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT
2236	A	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
2236	B	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
15	A	3.03	24.6	0.488	<0.02	<0.05	18.0	0.144	0.201	<0.02	0.01
15	B	2.56	17.0	0.368	<0.02	<0.05	11.3	0.038	0.070	<0.02	<0.02
19	A	0.135	17.0	0.368	<0.02	<0.05	11.3	<0.02	0.01	<0.02	<0.02
19	B	0.477	0.165	0.141	<0.02	<0.05	4.64	<0.02	0.04	<0.02	<0.02
31	A	<0.02	0.013	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
31	B	<0.02	0.014	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02

Table A6
Results of TCLP for Metals for Untreated Umatilla Army Depot

Soil	Replicate	mg/kg								
		As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
2236	A	NA	NA	NA	2.5	NA	0.17	0.58	NA	NA
2236	B	NA	NA	NA	9.0	NA	0.38	1.90	NA	NA
15	A	<0.003	6.6	<0.006	0.44	0.035	0.35	0.35	0.012	0.002
15	B	<0.003	18.0	<0.006	0.42	0.051	0.11	1.1	0.019	<0.002
19	A	0.009	10.0	NA	3.0	NA	<0.013	13.0	1.1	NA
19	B	0.006	16.0	NA	1.3	NA	<0.103	25.0	0.82	NA
31	A	NA	NA	NA	0.002	NA	<0.013	0.01	NA	NA
31	B	NA	NA	NA	0.002	NA	0.013	0.006	NA	NA

Appendix B
Results of Initial Screening Test for Umatilla Army Depot Soils

Table B1
Results of Initial Screen Test Cone Index (CI) Test on Soil 2236, Cement Binder

BSR	WSR	Replicate	Cone Index, psi 2 hr	4 hr	8 hr	24 hr	48 hr
0.1	0.1	A	185	425	750	750	750
0.1	0.1	B	190	400	750	750	750
0.1	0.3	A	FL[1]	FL	20	175	300
0.1	0.3	B	FL	FL	20	200	225
0.5	0.1	A	575	750	750	750	750
0.5	0.1	B	550	750	750	750	750
0.5	0.3	A	20	90	625	750	750
0.5	0.3	B	20	65	750	750	750

[1] FL: Denotes free liquid present on the surface of the sample.

Table B2
Results of Initial Screen Test CI Test on Soil 2236, Cement/Fly Ash Binder

BSR	WSR	Replicate	Cone Index, psi 2 hr	4 hr	8 hr	24 hr	48 hr
0.1/0.1	0.1	A	230	575	750	750	750
0.1/0.1	0.1	B	210	550	750	750	750
0.1/0.1	0.3	A	0	0	25	200	350
0.1/0.1	0.3	B	0	0	40	200	350
0.4/0.4	0.1	A	250[1]	450[1]	750[1]	750[1]	750[1]
0.4/0.4	0.1	B	225[1]	350[1]	750[1]	750[1]	750[1]
0.4/0.4	0.3	A	135	400	750	750	750
0.4/0.4	0.3	B	170	400	750	750	750

[1] Denotes that sample crumbled during CI test.

Table B3
Results of Initial Screen Test CI Test on Soil 15, Cement Binder

BSR	WSR	Replicate	Cone Index, psi				
			2 hr	4 hr	8 hr	24 hr	48 hr
0.1	0.1	A	170	200[1]	350	750	750
0.1	0.1	B	150	175[1]	350	750	750
0.1	0.3	A	0	30	43	140	165
0.1	0.3	B	0	18	35	210	238
0.5	0.1	A	400	450	750	750	750
0.5	0.1	B	400	650	750	750	750
0.5	0.3	A	40	110	525	750	750
0.5	0.3	B	35	115	525	750	750

[1] Denotes that sample crumbled during CI test.

Table B4
Results of Initial Screen Test CI Test on Soil 15, Cement/Fly Ash Binder

BSR	WSR	Replicate	Cone Index, psi				
			2 hr	4 hr	8 hr	24 hr	48 hr
0.1/0.1	0.1	A	250	252	525	750	750
0.1/0.1	0.1	B	300	338	575	750	750
0.1/0.1	0.3	A	10	30	33	220	350
0.1/0.1	0.3	B	10	30	35	215	350
0.4/0.4	0.1	A	275[1]	680[1]	700	750	750
0.4/0.4	0.1	B	350[1]	675	750	750	750
0.4/0.4	0.3	A	200	600	750	750	750
0.4/0.4	0.3	B	215	450	600	750	750

[1] Denotes that sample crumbled during CI test.

Table B5
Results of Initial Screen Test CI Test on Soil 19, Cement Binder

BSR	WSR	Replicate	Cone Index, psi 2 hr	4 hr	8 hr	24 hr	48 hr
0.1	0.1	A	180	120	450	385	675
0.1	0.1	B	180	100	375	375	700
0.1	0.3	A	0	30	20	53	165
0.1	0.3	B	0	0	33	68	180
0.5	0.1	A	250	300[1]	750	750[1]	750[1]
0.5	0.1	B	325	400[1]	750	750[1]	750
0.5	0.3	A	0	10	3	18	53
0.5	0.3	B	5	20	35	65	750

[1] Denotes that sample crumbled during CI test.

Table B6
Results of Initial Screen Test CI Test on Soil 19, Cement/Fly Ash Binder

BSR	WSR	Replicate	Cone Index, psi 2 hr	4 hr	8 hr	24 hr	48 hr
0.1/0.1	0.1	A	155	200	245	350	750
0.1/0.1	0.1	B	180	225	350	438	750
0.1/0.1	0.3	A	0	8	20	45	90
0.1/0.1	0.3	B	0	3	10	40	170
0.4/0.4	0.1	A	325	365	425[1]	450[1]	750
0.4/0.4	0.1	B	300	440	475[1]	500	750
0.4/0.4	0.3	A	100	125	375[1]	750	750
0.4/0.4	0.3	B	100	140	225	380	750

[1] Denotes that sample crumbled during CI test.

Table B7
Results of Initial Screen Test CI Test on Soil 31, Cement Binder

BSR	WSR	Replicate	Cone Index, psi				
			2 hr	4 hr	8 hr	24 hr	48 hr
0.1	0.1	A	135	185	330	750	750
0.1	0.1	B	180	193	250	750	750
0.1	0.3	A	275	425	750	750	750
0.1	0.3	B	230	355	750	750	750
0.5	0.1	A	10	23	40	205	450
0.5	0.1	B	18	33	88	280	450
0.5	0.3	A	30	50	538	750	750
0.5	0.3	B	13	45	480	750	750

Table B8
Results of Initial Screen Test CI Test on Soil 31, Cement/Fly Ash Binder

BSR	WSR	Replicate	Cone Index, psi				
			2 hr	4 hr	8 hr	24 hr	48 hr
0.1/0.1	0.1	A	190	350	440	750	750
0.1/0.1	0.1	B	240	300	405	750	750
0.1/0.1	0.3	A	10	23	75	313	445
0.1/0.1	0.3	B	5	20	73	255	435
0.4/0.4	0.1	A	305	300	650[1]	750	750
0.4/0.4	0.1	B	123	225	400[1]	750	750
0.4/0.4	0.3	A	80	200	750	750	750
0.4/0.4	0.3	B	88	200	750	750	750

[1] Denotes that sample crumbled during CI test.

Table B9
Results of Metals for Toxicity Characteristic Leaching Procedure (TCLP) for Initial Screening Test for Soil 2236

Binder Ratio	Water Ratio	Replicate	mg/ℓ								
			As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
0.1 Cement	0.1	A	NA[1]	NA	NA	<0.01	NA	0.475	<0.01	NA	NA
0.1 Cement	0.1	B	NA	NA	NA	<0.01	NA	0.409	<0.01	NA	NA
0.1 Cement	0.3	A	NA	NA	NA	3.4	NA	<0.05	<0.01	NA	NA
0.1 Cement	0.3	B	NA	NA	NA	3.55	NA	<0.05	<0.01	NA	NA
0.5 Cement	0.1	A	NA	NA	NA	<0.01	NA	0.193	<0.01	NA	NA
0.5 Cement	0.1	B	NA	NA	NA	<0.01	NA	0.198	<0.01	NA	NA
0.5 Cement	0.3	A	NA	NA	NA	<0.01	NA	0.201	<0.01	NA	NA
0.5 Cement	0.3	B	NA	NA	NA	<0.01	NA	0.172	<0.01	NA	NA
0.1/0.1 Cement/Fly Ash	0.1	A	NA	NA	NA	2.84	NA	<0.05	<0.01	NA	NA
0.1/0.1 Cement/Fly Ash	0.1	B	NA	NA	NA	4.2	NA	<0.05	<0.01	NA	NA
0.1/0.1 Cement/Fly Ash	0.3	A	NA	NA	NA	1.93	NA	0.219	<0.01	NA	NA
0.1/0.1 Cement/Fly Ash	0.3	B	NA	NA	NA	4.27	NA	<0.05	<0.01	NA	NA
0.4/0.4 Cement/Fly Ash	0.1	A	NA	NA	NA	<0.01	NA	0.249	<0.01	NA	NA
0.4/0.4 Cement/Fly Ash	0.1	B	NA	NA	NA	<0.01	NA	0.251	<0.01	NA	NA
0.4/0.4 Cement/Fly Ash	0.3	A	NA	NA	NA	<0.01	NA	2.257	<0.01	NA	NA
0.4/0.4 Cement/Fly Ash	0.3	B	Sample Was Lost								

[1] NA: Denotes samples was not analyzed for this compound.

Table B10
Results of Metals for TCLP for Initial Screening Test for Soil 15

Binder Ratio	Water Ratio	Replicate	mg/ℓ								
			As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
0.1 Cement	0.1	A	<0.02	4.65	<0.01	0.398	<0.05	<0.05	1.57	<0.10	<0.003
0.1 Cement	0.1	B	<0.02	5.27	<0.01	0.293	<0.05	<0.05	0.569	<0.10	<0.003
0.1 Cement	0.3	A	<0.02	3.20	<0.01	0.267	<0.05	<0.05	<0.10	<0.10	<0.003
0.1 Cement	0.3	B	<0.02	3.36	<0.01	0.344	<0.05	<0.05	0.274	<0.10	<0.003
0.5 Cement	0.1	A	<0.02	1.12	<0.01	<0.01	<0.05	0.107	<0.10	<0.10	<0.003
0.5 Cement	0.1	B	<0.02	1.94	<0.01	<0.01	<0.05	0.129	<0.10	<0.10	<0.003
0.5 Cement	0.3	A	<0.02	2.59	<0.01	<0.01	<0.05	0.223	<0.10	<0.10	<0.003
0.5 Cement	0.3	B	<0.02	2.48	<0.01	<0.01	<0.05	0.207	<0.10	<0.10	<0.003
0.1/0.1 Cement/Fly Ash	0.1	A	<0.02	1.32	<0.01	<0.01	<0.05	0.202	<0.10	<0.10	<0.003
0.1/0.1 Cement/Fly Ash	0.1	B	<0.02	1.09	<0.01	<0.01	<0.05	0.194	<0.10	<0.10	<0.003
0.1/0.1 Cement/Fly Ash	0.3	A	<0.02	2.26	<0.01	<0.01	<0.05	0.122	<0.10	<0.10	<0.003
0.1/0.1 Cement/Fly Ash	0.3	B	<0.02	1.40	<0.01	<0.01	<0.05	0.126	<0.10	<0.10	<0.003
0.4/0.4 Cement/Fly Ash	0.1	A	<0.02	1.60	<0.01	<0.01	<0.05	0.169	<0.10	<0.10	<0.003
0.4/0.4 Cement/Fly Ash	0.1	B	<0.02	1.55	<0.01	<0.01	<0.05	0.186	<0.10	<0.10	<0.003
0.4/0.4 Cement/Fly Ash	0.3	A	<0.02	3.66	<0.01	0.282	<0.05	<0.05	0.287	<0.10	<0.003
0.4/0.4 Cement/Fly Ash	0.3	B	<0.02	2.51	<0.01	0.239	<0.05	0.074	0.167	<0.10	<0.003

Table B11
Results of Metals for TCLP for Initial Screening Test for Soil 19

Binder Ratio	Water Ratio	Replicate	mg/ℓ								
			As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
0.1 Cement	0.1	A	<0.02	1.85	NA[1]	<0.01	NA	<0.05	<0.10	0.106	NA
0.1 Cement	0.1	B	<0.02	2.09	NA	<0.01	NA	<0.05	<0.10	0.191	NA
0.1 Cement	0.3	A	<0.02	3.02	NA	0.182	NA	<0.05	0.23	0.165	NA
0.1 Cement	0.3	B	<0.02	1.47	NA	<0.01	NA	<0.05	<0.10	0.170	NA
0.5 Cement	0.1	A	<0.02	1.95	NA	<0.01	NA	<0.05	<0.10	<0.10	NA
0.5 Cement	0.1	B	<0.02	1.88	NA	<0.01	NA	<0.05	0.653	<0.10	NA
0.5 Cement	0.3	A	<0.02	3.48	NA	<0.01	NA	<0.05	0.416	<0.10	
0.5 Cement	0.3	B	<0.02	1.98	NA	<0.01	NA	<0.05	1.44	<0.10	NA
0.1/0.1 Cement/Fly Ash	0.1	A	<0.02	4.14	NA	0.441	NA	<0.05	0.523	<0.10	NA
0.1/0.1 Cement/Fly Ash	0.1	B	<0.02	3.82	NA	<0.01	NA	<0.05	<0.10	0.265	NA
0.1/0.1 Cement/Fly Ash	0.3	A	<0.02	2.68	NA	<0.01	NA	<0.05	<0.10	0.114	NA
0.1/0.1 Cement/Fly Ash	0.3	B	<0.02	1.97	NA	<0.01	NA	<0.05	<0.10	0.167	NA
0.4/0.4 Cement/Fly Ash	0.1	A	<0.02	2.36	NA	<0.01	NA	<0.05	1.20	<0.10	NA
0.4/0.4 Cement/Fly Ash	0.1	B	<0.02	2.92	NA	<0.01	NA	<0.05	1.42	<0.10	NA
0.4/0.4 Cement/Fly Ash	0.3	A	<0.02	1.36	NA	<0.01	NA	<0.05	0.758	<0.10	NA
0.4/0.4 Cement/Fly Ash	0.3	B	<0.02	4.04	NA	<0.01	NA	<0.05	2.97	<0.10	NA

[1] NA: Denotes samples was not analyzed for this compound.

Table B12
Results of Metals for TCLP for Initial Screening Test for Soil 31

Binder Ratio	Water Ratio	Replicate	mg/ℓ								
			As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
0.1 Cement	0.1	A	<0.02	NA[1]	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.1 Cement	0.1	B	<0.02	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.1 Cement	0.3	A	<0.02	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.1 Cement	0.3	B	<0.02	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.5 Cement	0.1	A	<0.02	NA	NA	<0.01	NA	0.071	<0.10	NA	NA
0.5 Cement	0.1	B	<0.02	NA	NA	<0.01	NA	0.074	<0.10	NA	NA
0.5 Cement	0.3	A	<0.02	NA	NA	<0.01	NA	0.071	<0.10	NA	NA
0.5 Cement	0.3	B	<0.02	NA	NA	<0.10	NA	0.62	<0.10	NA	NA
0.1/0.1 Cement/Fly Ash	0.1	A	<0.02	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.1/0.1 Cement/Fly Ash	0.1	B	<0.02	NA	NA	0.011	NA	<0.05	<0.10	NA	NA
0.1/0.1 Cement/Fly Ash	0.3	A	<0.02	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.1/0.1 Cement/Fly Ash	0.3	B	<0.02	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.4/0.4 Cement/Fly Ash	0.1	A	<0.02	NA	NA	0.014	NA	<0.05	<0.10	NA	NA
0.4/0.4 Cement/Fly Ash	0.1	B	<0.02	NA	NA	0.012	NA	<0.05	<0.10	NA	NA
0.4/0.4 Cement/Fly Ash	0.3	A	<0.02	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.4/0.4 Cement/Fly Ash	0.3	B	<0.02	NA	NA	0.011	NA	<0.05	<0.10	NA	NA

[1] NA: Denotes sample was not analyzed for this compound.

Table B13
Results of Explosives for TCLP for Initial Screening Test for Soil 2236

Binder Ratio	Water Ratio	Replicate	mg/ℓ										
			HMX	RDX	TNB	DNB	TERTYL	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT	NB
0.1 Cement	0.1	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND[1]
0.1 Cement	0.1	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.1 Cement	0.3	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.1 Cement	0.3	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.1	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.1	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.3	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.3	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.1	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.1	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.3	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.3	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.1	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.1	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.3	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.3	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND

[1] ND: Denotes that compound was not detected in sample.

Table B14
Results of Explosives for TCLP for Initial Screening Test for Soil 15

Binder Ratio	Water Ratio	Replicate	mg/ℓ										
			HMX	RDX	TNB	DNB	TERTYL	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT	NB
0.1 Cement	0.1	A	2.37	1.12	0.044	<0.02	<0.05	<0.02	0.266	0.074	<0.02	<0.02	ND[1]
0.1 Cement	0.1	B	0.99	2.64	0.073	<0.02	<0.05	0.696	0.696	0.014	<0.02	<0.02	ND
0.1 Cement	0.3	A	1.90	0.043	0.013	<0.02	<0.05	<0.02	<0.02	0.039	<0.02	<0.02	ND
0.1 Cement	0.3	B	0.040	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	0.009	<0.02	<0.02	ND
0.5 Cement	0.1	A	3.80	17.4	0.051	<0.02	<0.05	2.47	2.47	0.086	<0.02	<0.02	ND
0.5 Cement	0.1	B	2.37	6.77	0.08	<0.02	<0.05	2.00	2.00	0.019	<0.02	<0.02	ND
0.5 Cement	0.3	A	3.20	6.19	0.126	<0.02	<0.05	2.73	2.73	0.072	<0.02	<0.02	ND
0.5 Cement	0.3	B	1.08	0.972	0.037	<0.02	<0.05	0.217	0.217	0.012	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.1	A	2.59	1.40	0.059	<0.02	<0.05	<0.02	<0.02	0.048	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.1	B	1.19	2.44	0.071	<0.02	<0.05	0.639	0.064	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.3	A	2.76	5.80	0.113	<0.02	<0.05	1.74	1.74	0.026	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.3	B	0.333	0.278	0.11	<0.02	<0.05	0.028	0.028	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.1	A	1.32	0.47	0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.1	B	0.294	1.28	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.3	A	1.34	3.74	0.045	<0.02	<0.05	0.536	0.536	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.3	B	0.37	0.147	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND

[1] ND: Denotes that compound was not detected in sample.

Table B15
Results of Explosives for TCLP for Initial Screening Test for Soil 19

Binder Ratio	Water Ratio	Replicate	mg/ℓ										
			HMX	RDX	TNB	DNB	TERTYL	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT	NB
0.1 Cement	0.1	A	0.129	0.097	0.171	<0.02	<0.05	4.6	<0.02	<0.02	<0.02	<0.02	ND[1]
0.1 Cement	0.1	B	0.356	0.388	0.187	<0.02	<0.05	5.81	<0.02	<0.02	<0.02	<0.02	ND
0.1 Cement	0.3	A	0.065	0.039	0.111	<0.02	<0.05	0.774	<0.02	<0.02	<0.02	<0.02	ND
0.1 Cement	0.3	B	0.252	0.186	0.159	<0.02	<0.05	4.98	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.1	A	0.06	<0.02	0.005	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.1	B	0.177	<0.02	0.011	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.3	A	0.049	<0.02	0.007	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.3	B	0.084	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.1	A	0.076	0.072	0.082	<0.02	<0.05	0.798	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.1	B	2.15	15.3	0.306	<0.02	<0.05	8.04	0.022	0.017	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.3	A	0.052	0.042	0.305	<0.02	<0.05	0.341	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.3	B	0.222	0.167	0.129	<0.02	<0.05	2.83	<0.02	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.1	A	0.021	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.1	B	0.302	<0.02	0.084	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.3	A	0.03	<0.02	<0.02	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.3	B	0.128	<0.02	0.011	<0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	ND

[1] ND: Denotes that compound was not detected in sample.

Table B16
Results of Explosives for TCLP for Initial Screening Test for Soil 31

Binder Ratio	Water Ratio	Replicate	mg/ℓ										
			HMX	RDX	TNB	DNB	TERTYL	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT	NB
0.1 Cement	0.1	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND[1]
0.1 Cement	0.1	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.1 Cement	0.3	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.1 Cement	0.3	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.1	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.1	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.3	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.3	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.1	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.1	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.3	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.3	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.1	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.1	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.3	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND
0.4/0.4 Cement/Fly Ash	0.3	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND

[1] ND: Denotes that compound was not detected in sample.

Appendix C
Results Of Physical and Chemical Tests For Detailed Evaluation for Umatilla Army Depot Soils

Table C1
Results of Physical Tests for Detailed Evaluation of Umatilla Army Depot, Soil 2236

BSR	WSR	Replicate	Moisture Content, %	Bulk Density lb/ft^3	Slump in.
0.1 Cement	0.2	A	19	111	12.0
0.1 Cement	0.2	B	19	116.5	
0.3 Cement	0.2	A	13	133	12.0
0.3 Cement	0.2	B	14	133	
0.5 Cement	0.2	A	9	142.5	4.38
0.5 Cement	0.2	B	9	137	
0.7 Cement	0.2	A	6	149	0.56
0.7 Cement	0.2	B	7	147	
0.1/0.1 Cement/Fly Ash	0.2	A	17	119.5	12.0
0.1/0.1 Cement/Fly Ash	0.2	B	15	118.5	
0.1/0.3 Cement/Fly Ash	0.2	A	14	115	3.0
0.1/0.3 Cement/Fly Ash	0.2	B	14	123	
0.3/0.1 Cement/Fly Ash	0.2	A	11	123	8.0
0.3/0.1 Cement/Fly Ash	0.2	B	12	133	
0.3/0.3 Cement/Fly Ash	0.2	A	10	131.5	0.56
0.3/0.3 Cement/Fly Ash	0.2	B	10	130.5	

Table C2
Results of Physical Tests for Detailed Evaluation of Umatilla Army Depot, Soil 15

BSR	WSR	Replicate	Moisture Content, %	Bulk Density lb/ft^3	Slump in.
0.1 Cement	0.2	A	17	122	12.0
0.1 Cement	0.2	B	16	124	
0.3 Cement	0.2	A	11	133	2.5
0.3 Cement	0.2	B	11	132.5	
0.5 Cement	0.2	A	8	133	1.0
0.5 Cement	0.2	B	8	130.5	
0.7 Cement	0.2	A	7	126	0.13
0.7 Cement	0.2	B	7	125	
0.1/0.1 Cement/Fly Ash	0.2	A	15	126	12.0
0.1/0.1 Cement/Fly Ash	0.2	B	15	119.5	
0.1/0.3 Cement/Fly Ash	0.2	A	12	119.5	0.5
0.1/0.3 Cement/Fly Ash	0.2	B	13	118.5	
0.3/0.1 Cement/Fly Ash	0.2	A	8	130	1.0
0.3/0.1 Cement/Fly Ash	0.2	B	9	128.5	
0.3/0.3 Cement/Fly Ash	0.2	A	9	114.5	0.0
0.3/0.3 Cement/Fly Ash	0.2	B	8	118.5	

Table C3
Results of Physical Tests for Detailed Evaluation of Umatilla Army Depot, Soil 19

BSR	WSR	Replicate	Moisture Content, %	Bulk Density lb/ft^3	Slump in.
0.1 Cement	0.2	A	12	101	12.0
0.1 Cement	0.2	B	12	105.5	
0.3 Cement	0.2	A	9	116	12.0
0.3 Cement	0.2	B	8	123	
0.5 Cement	0.2	A	12	121	1.0
0.5 Cement	0.2	B	8	129.5	
0.7 Cement	0.2	A	10	130	0.13
0.7 Cement	0.2	B	6	131.5	
0.1/0.1 Cement/Fly Ash	0.2	A	13	108.5	12.0
0.1/0.1 Cement/Fly Ash	0.2	B	17	107	
0.1/0.3 Cement/Fly Ash	0.2	A	10	107	0.75
0.1/0.3 Cement/Fly Ash	0.2	B	10	112	
0.3/0.1 Cement/Fly Ash	0.2	A	8	120	2.0
0.3/0.1 Cement/Fly Ash	0.2	B	11	117	
0.3/0.3 Cement/Fly Ash	0.2	A	10	118.5	0.25
0.3/0.3 Cement/Fly Ash	0.2	B	10	124	

Table C4
Results of Physical Tests for Detailed Evaluation of Umatilla Army Depot, Soil 31

BSR	WSR	Replicate	Moisture Content, %	Bulk Density lb/ft^3	Slump in.
0.1 Cement	0.2	A	13	117	12.0
0.1 Cement	0.2	B	12	115.5	
0.3 Cement	0.2	A	9	121	12.0
0.3 Cement	0.2	B	8	128	
0.5 Cement	0.2	A	7	135	1.75
0.5 Cement	0.2	B	8	133	
0.7 Cement	0.2	A	10	137	0.25
0.7 Cement	0.2	B	6	141	
0.1/0.1 Cement/Fly Ash	0.2	A	12	120.5	12.0
0.1/0.1 Cement/Fly Ash	0.2	B	12	122	
0.1/0.3 Cement/Fly Ash	0.2	A	10	126	1.5
0.1/0.3 Cement/Fly Ash	0.2	B	10	122	
0.3/0.1 Cement/Fly Ash	0.2	A	9	130	3.86
0.3/0.1 Cement/Fly Ash	0.2	B	10	129	
0.3/0.3 Cement/Fly Ash	0.2	A	9	134.5	0.25
0.3/0.3 Cement/Fly Ash	0.2	B	8	129	

Table C5
Results of CI for Detailed Evaluation for Umatilla Army Depot Soil 2236

			Cone Index, psi				
BSR	WSR	Replicate	2 hr	4 hr	8 hr	24 hr	48 hr
Cement Binder							
0.1	0.2	A	13	28	93	500	605
0.1	0.2	B	5	18	45	330	510
0.3	0.2	A	10	50	570	750	750
0.3	0.2	B	20	75	750	750	750
0.5	0.2	A	68	280	750	750	750
0.5	0.2	B	95	325	750	750	750
0.7	0.2	A	233	750	750	750	750
0.7	0.2	B	160	750	750	750	750
Cement/Fly Ash Binder							
0.1/0.1	0.2	A	10	18	88	370	520
0.1/0.1	0.2	B	10	45	153	590	650
0.1/0.3	0.2	A	130	195	530	750	750
0.1/0.3	0.2	B	145	270	570	750	750
0.3/0.1	0.2	A	50	180	750	750	750
0.3/0.1	0.2	B	40	200	750	750	750
0.3/0.3	0.2	A	205	750	750	750	750
0.3/0.3	0.2	B	198	750	750	750	750

Table C6
Results of Cone Index (CI) for Detailed Evaluation for Umatilla Army Depot Soil 15

BSR	WSR	Replicate	Cone Index, psi				
			2 hr	4 hr	8 hr	24 hr	48 hr
Cement Binder							
0.1	0.2	A	28	70	100	265	615
0.1	0.2	B	50	88	150	253	750
0.3	0.2	A	93	210	750	750	750
0.3	0.2	B	63	113	245	750	750
0.5	0.2	A	135	425	750	750	750
0.5	0.2	B	63	85	138	120	180
0.7	0.2	A	258	575	750	750	750
0.7	0.2	B	120	150	135	210	130
Cement/Fly Ash Binder							
0.1/0.1	0.2	A	90	130	205	580	680
0.1/0.1	0.2	B	60	98	85	190	283
0.1/0.3	0.2	A	198	180	480	750	750
0.1/0.3	0.2	B	110	220	290	415	750
0.3/0.1	0.2	A	115	405	750	750	750
0.3/0.1	0.2	B	190	290	750	750	750
0.3/0.3	0.2	A	450	625	750	750	750
0.3/0.3	0.2	B	450	590	750	750	750

Table C7
Results of CI for Detailed Evaluation for Umatilla Army Depot Soil 19

BSR	WSR	Replicate	Cone Index, psi				
			2 hr	4 hr	8 hr	24 hr	48 hr
Cement Binder							
0.1	0.2	A	10	28	78	225	530
0.1	0.2	B	10	25	50	250	490
0.3	0.2	A	20	60	230	750	750
0.3	0.2	B	13	35	55	650	750
0.5	0.2	A	20	28	68	100	125
0.5	0.2	B	10	40	75	750	750
0.7	0.2	A	115	130	150	425	445
0.7	0.2	B	90	115	125	325	415
Cement/Fly Ash Binder							
0.1/0.1	0.2	A	5	18	53	68	130
0.1/0.1	0.2	B	10	13	20	43	75
0.1/0.3	0.2	A	38	68	110	170	385
0.1/0.3	0.2	B	25	60	68	95	195
0.3/0.1	0.2	A	20	50	78	255	750
0.3/0.1	0.2	B	75	28	90	80	105
0.3/0.3	0.2	A	220	250	425	750	750
0.3/0.3	0.2	B	155	250	410	425	750

Table C8
Results of CI for Detailed Evaluation for Umatilla Army Depot Soil 31

BSR	WSR	Replicate	Cone Index, psi				
			2 hr	4 hr	8 hr	24 hr	48 hr
Cement Binder							
0.1	0.2	A	20	38	100	625	750
0.1	0.2	B	15	25	90	550	750
0.3	0.2	A	20	63	425	750	750
0.3	0.2	B	20	58	450	750	750
0.5	0.2	A	50	255	750	750	750
0.5	0.2	B	45	290	750	750	750
0.7	0.2	A	125	600	750	750	750
0.7	0.2	B	150	660	750	750	750
Cement/Fly Ash Binder							
0.1/0.1	0.2	A	20	65	140	400	650
0.1/0.1	0.2	B	25	85	128	475	650
0.1/0.3	0.2	A	123	360	440	750	750
0.1/0.3	0.2	B	83	240	380	650	750
0.3/0.1	0.2	A	80	170	750	750	750
0.3/0.1	0.2	B	70	210	750	750	750
0.3/0.3	0.2	A	223	480	750	750	750
0.3/0.3	0.2	B	160	435	750	750	750

Table C9
Results of Unconfined Compressive Strength (UCS) for Detailed Evaluation for Umatilla Army Depot Soil 2236

BSR	WSR	Replicate	UCS, psi		
			5 day	10 day	14 day
Cement Binder					
0.1	0.2	A	118	153	288
0.1	0.2	B	112	116	205
0.3	0.2	A	944	1,197	1,121
0.3	0.2	B	935	1,526	1,808
0.5	0.2	A	2,504	1,886	2,406
0.5	0.2	B	2,671	2,665	2,577
0.7	0.2	A	3,721	4,543	3,599
0.7	0.2	B	2,849	3,998	5,646
Cement/Fly Ash Binder					
0.1/0.1	0.2	A	159	260	392
0.1/0.1	0.2	B	149	214	496
0.1/0.3	0.2	A	285	448	589
0.1/0.3	0.2	B	271	466	688
0.3/0.1	0.2	A	887	2,018	1,915
0.3/0.1	0.2	B	973	1,696	1,811
0.3/0.3	0.2	A	1,353	2,558	1,753
0.3/0.3	0.2	B	1,167	2,508	2,369

Table C10
Results of UCS for Detailed Evaluation for Umatilla Army Depot Soil 15

BSR	WSR	Replicate	UCS, psi		
			5 day	10 day	14 day
Cement Binder					
0.1	0.2	A	89	135	167
0.1	0.2	B	105	139	167
0.3	0.2	A	788	1,465	1,398
0.3	0.2	B	995	1,197	1,541
0.5	0.2	A	1,904	3,033	1,806
0.5	0.2	B	324	1,052	1,275
0.7	0.2	A	2,901	3,198	1,943
0.7	0.2	B	76	106	108
Cement/Fly Ash Binder					
0.1/0.1	0.2	A	192	307	329
0.1/0.1	0.2	B	48	91	87
0.1/0.3	0.2	A	347	612	646
0.1/0.3	0.2	B	217	302	341
0.3/0.1	0.2	A	1,755	2,604	1,976
0.3/0.1	0.2	B	1,745	2,405	2,459
0.3/0.3	0.2	A	647	1,468	1,031
0.3/0.3	0.2	B	665	1,774	2,008

Table C11
Results of UCS for Detailed Evaluation for Umatilla Army Depot Soil 19

BSR	WSR	Replicate	UCS, psi		
			5 day	10 day	14 day
Cement Binder					
0.1	0.2	A	112	182	165
0.1	0.2	B	94	158	149
0.3	0.2	A	1,136	1,687	1,112
0.3	0.2	B	694	1,169	1,001
0.5	0.2	A	31	50	114
0.5	0.2	B	1,618	2,316	1,861
0.7	0.2	A	81	99	152
0.7	0.2	B	203	705	1,229
Cement/Fly Ash Binder					
0.1/0.1	0.2	A	27	19	33
0.1/0.1	0.2	B	28	20	28
0.1/0.3	0.2	A	68	74	86
0.1/0.3	0.2	B	40	41	54
0.3/0.1	0.2	A	234	758	954
0.3/0.1	0.2	B	31	304	67
0.3/0.3	0.2	A	789	719	1,048
0.3/0.3	0.2	B	236	428	552

Table C12
Results of UCS for Detailed Evaluation for Umatilla Army Depot Soil 31

BSR	WSR	Replicate	UCS, psi		
			5 day	10 day	14 day
Cement Binder					
0.1	0.2	A	99	165	228
0.1	0.2	B	109	222	267
0.3	0.2	A	915	1,087	1,505
0.3	0.2	B	806	1,412	1,385
0.5	0.2	A	2,508	2,319	3,012
0.5	0.2	B	2,114	2,129	3,065
0.7	0.2	A	3,101	3,062	4,404
0.7	0.2	B	2,671	1,651	3,134
Cement/Fly Ash Binder					
0.1/0.1	0.2	A	118	214	260
0.1/0.1	0.2	B	120	232	292
0.1/0.3	0.2	A	284	781	569
0.1/0.3	0.2	B	270	450	554
0.3/0.1	0.2	A	1,049	1,649	1,725
0.3/0.1	0.2	B	976	1,658	1,692
0.3/0.3	0.2	A	1,659	1,234	2,286
0.3/0.3	0.2	B	1,224	1,856	2,324

Table C13
Results for Metals for 2-Day Toxicity Characteristic Leaching Procedure (TCLP) for Detailed Evaluation of Umatilla Army Depot, Soil 2236

Binder Ratio	Water Ratio	Replicate	mg/ℓ								
			As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
0.1 Cement	0.2	A	NA[1]	NA	NA	<0.01	NA	0.317	<0.10	NA	NA
0.1 Cement	0.2	B	NA	NA	NA	<0.01	NA	0.462	<0.10	NA	NA
0.3 Cement	0.2	A	NA	NA	NA	<0.01	NA	0.320	<0.10	NA	NA
0.3 Cement	0.2	B	NA	NA	NA	0.012	NA	0.447	<0.10	NA	NA
0.5 Cement	0.2	A	NA	NA	NA	<0.01	NA	0.103	<0.10	NA	NA
0.5 Cement	0.2	B	NA	NA	NA	<0.01	NA	0.095	<0.10	NA	NA
0.7 Cement	0.2	A	NA	NA	NA	<0.01	NA	0.085	<0.10	NA	NA
0.7 Cement	0.2	B	NA	NA	NA	<0.01	NA	0.083	<0.10	NA	NA
0.1/0.1 Cement/Fly Ash	0.2	A	NA	NA	NA	0.034	NA	0.335	<0.01	NA	NA
0.1/0.1 Cement/Fly Ash	0.2	B	NA	NA	NA	4.77	NA	0.259	0.604	NA	NA
0.1/0.3 Cement/Fly Ash	0.2	A	NA	NA	NA	2.50	NA	0.372	2.31	NA	NA
0.1/0.3 Cement/Fly Ash	0.2	B	NA	NA	NA	6.15	NA	0.587	1.10	NA	NA
0.3/0.1 Cement/Fly Ash	0.2	A	NA	NA	NA	<0.01	NA	2.88	<0.01	NA	NA
0.3/0.1 Cement/Fly Ash	0.2	B	NA	NA	NA	<0.01	NA	0.368	<0.01	NA	NA
0.3/0.3 Cement/Fly Ash	0.2	A	NA	NA	NA	<0.01	NA	0.210	<0.01	NA	NA
0.3/0.3 Cement/Fly Ash	0.2	B	NA	NA	NA	<0.01	NA	0.257	<0.10	NA	NA

[1] NA: Denotes that sample was not analyzed for this compound.

Table C14
Results for Metals for 2-Day TCLP for Umatilla Army Depot, Soil 15

Binder Ratio	Water Ratio	Replicate	mg/ℓ								
			As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
0.1 Cement	0.2	A	<0.20	1.30	<0.01	0.710	<0.05	0.344	0.318	<0.10	<0.003
0.1 Cement	0.2	B	<0.20	6.25	<0.01	0.456	0.053	0.748	1.369	<0.10	0.004
0.3 Cement	0.2	A	<0.20	2.52	<0.01	0.113	<0.05	0.220	<0.10	<0.10	0.005
0.3 Cement	0.2	B	<0.20	1.38	<0.01	<0.01	<0.05	<0.05	<0.10	<0.10	0.004
0.5 Cement	0.2	A	<0.20	2.07	<0.01	<0.01	<0.05	0.203	<0.10	<0.10	0.003
0.5 Cement	0.2	B	<0.20	2.12	<0.01	<0.01	<0.05	0.157	<0.10	<0.10	0.004
0.7 Cement	0.2	A	<0.20	3.92	<0.01	<0.01	<0.05	0.081	<0.10	<0.10	<0.003
0.7 Cement	0.2	B	<0.20	1.62	<0.01	<0.01	<0.05	0.081	<0.10	<0.10	<0.003
0.1/0.1 Cement/Fly Ash	0.2	A	<0.20	4.54	<0.01	0.102	<0.05	0.319	<0.10	<0.10	0.004
0.1/0.1 Cement/Fly Ash	0.2	B	0.231	1.40	<0.01	<0.01	<0.05	<0.05	<0.10	<0.10	0.004
0.1/0.3 Cement/Fly Ash	0.2	A	<0.20	3.54	<0.01	0.041	<0.05	0.264	<0.10	<0.10	0.003
0.1/0.3 Cement/Fly Ash	0.2	B	0.301	1.48	<0.01	<0.01	<0.05	<0.05	<0.10	<0.10	0.003
0.3/0.1 Cement/Fly Ash	0.2	A	<0.20	5.25	<0.01	<0.01	<0.05	0.152	<0.10	<0.10	<0.003
0.3/0.1 Cement/Fly Ash	0.2	B	<0.20	5.26	<0.01	<0.01	<0.05	0.157	<0.10	<0.10	<0.003
0.3/0.3 Cement/Fly Ash	0.2	A	<0.20	3.24	<0.01	<0.01	<0.05	<0.05	1.72	<0.10	<0.003
0.3/0.3 Cement/Fly Ash	0.2	B	<0.20	4.39	<0.01	<0.01	<0.05	0.175	0.201	<0.10	<0.003

Table C15
Results for Metals for 2-Day TCLP for Umatilla Army Depot, Soil 19

Binder Ratio	Water Ratio	Replicate	mg/ℓ								
			As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
0.1 Cement	0.2	A	<0.20	6.98	NA[1]	0.285	NA	<0.05	3.51	0.367	NA
0.1 Cement	0.2	B	<0.20	1.95	NA	0.372	NA	<0.05	1.28	0.362	NA
0.3 Cement	0.2	A	<0.20	5.64	NA	<0.01	NA	0.076	<0.10	<0.10	NA
0.3 Cement	0.2	B	<0.20	4.19	NA	<0.01	NA	0.072	<0.10	<0.10	NA
0.5 Cement	0.2	A	<0.20	2.32	NA	<0.01	NA	0.126	0.596	<0.10	NA
0.5 Cement	0.2	B	<0.20	4.56	NA	<0.01	NA	0.052	0.239	<0.10	NA
0.7 Cement	0.2	A	<0.20	2.77	NA	<0.01	NA	0.105	0.205	<0.10	NA
0.7 Cement	0.2	B	<0.20	2.72	NA	<0.01	NA	0.083	2.50	<0.10	NA
0.1/0.1 Cement/Fly Ash	0.2	A	<0.20	4.63	NA	0.685	NA	<0.05	3.73	<0.10	NA
0.1/0.1 Cement/Fly Ash	0.2	B	<0.20	5.56	NA	1.04	NA	<0.05	17.60	4.235	NA
0.1/0.3 Cement/Fly Ash	0.2	A	<0.20	4.14	NA	1.08	NA	<0.05	9.52	<0.104	NA
0.1/0.3 Cement/Fly Ash	0.2	B	<0.20	1.98	NA	1.23	NA	<0.05	19.70	0.133	NA
0.3/0.1 Cement/Fly Ash	0.2	A	<0.20	2.78	NA	<0.01	NA	0.100	0.152	<0.10	NA
0.3/0.1 Cement/Fly Ash	0.2	B	<0.20	2.01	NA	<0.01	NA	0.132	<0.10	<0.10	NA
0.3/0.3 Cement/Fly Ash	0.2	A	<0.20	2.62	NA	<0.01	NA	0.066	<0.10	<0.10	NA
0.3/0.3 Cement/Fly Ash	0.2	B	<0.20	2.24	NA	<0.01	NA	0.094	<0.10	<0.10	NA

[1] NA: Denotes that sample was not analyzed for this compound.

Table C16
Results of Metals for 2-Day TCLP for Umatilla Army Depot, Soil 31

Binder Ratio	Water Ratio	Replicate	mg/ℓ								
			As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
0.1 Cement	0.2	A	<0.20	NA[1]	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.1 Cement	0.2	B	<0.20	NA	NA	<0.01	NA	0.083	<0.10	NA	NA
0.3 Cement	0.2	A	<0.20	NA	NA	<0.01	NA	0.100	<0.10	NA	NA
0.3 Cement	0.2	B	<0.20	NA	NA	<0.01	NA	0.103	<0.10	NA	NA
0.5 Cement	0.2	A	<0.20	NA	NA	<0.01	NA	0.052	0.118	NA	NA
0.5 Cement	0.2	B	<0.20	NA	NA	<0.01	NA	0.072	<0.10	NA	NA
0.7 Cement	0.2	A	<0.20	NA	NA	<0.01	NA	0.061	<0.10	NA	NA
0.7 Cement	0.2	B	<0.20	NA	NA	<0.01	NA	0.075	<0.10	NA	NA
0.1/0.1 Cement/Fly Ash	0.2	A	<0.20	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.1/0.1 Cement/Fly Ash	0.2	B	<0.20	NA	NA	<0.01	NA	0.058	<0.10	NA	NA
0.1/0.3 Cement/Fly Ash	0.2	A	<0.20	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.1/0.3 Cement/Fly Ash	0.2	B	<0.20	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.3/0.1 Cement/Fly Ash	0.2	A	<0.20	NA	NA	<0.01	NA	0.104	<0.10	NA	NA
0.3/0.1 Cement/Fly Ash	0.2	B	<0.20	NA	NA	<0.01	NA	0.107	<0.10	NA	NA
0.3/0.3 Cement/Fly Ash	0.2	A	<0.20	NA	NA	<0.01	NA	0.098	<0.10	NA	NA
0.3/0.3 Cement/Fly Ash	0.2	B	<0.20	NA	NA	<0.01	NA	0.096	<0.10	NA	NA

[1] NA: Denotes that sample was not analyzed for this compound.

Table C17
Results of Explosives for 2-Day TCLP for Detailed Evaluation of Soil 15

Binder Ratio	Water Ratio	Replicate	mg/ℓ					
			HMX	RDX	TNB	DNB	TERTYL	TNT
0.1 Cement	0.2	A	3.43	10.8	0.206	<0.02	<0.05	2.92
0.1 Cement	0.2	B	0.03	26.8	4.454	<0.02	<0.05	0.17
0.3 Cement	0.2	A	2.96	9.29	0.13	<0.02	<0.05	2.67
0.3 Cement	0.2	B	3.74	31.5	0.45	<0.02	<0.05	26.8
0.5 Cement	0.2	A	1.74	0.773	0.072	<0.02	<0.05	<0.02
0.5 Cement	0.2	B	5.96	5.39	0.121	<0.02	<0.05	<0.02
0.7 Cement	0.2	A	0.94	0.12	0.02	<0.02	<0.05	<0.02
0.7 Cement	0.2	B	5.75	0.371	0.024	<0.02	<0.05	<0.02
0.1/0.1 Cement/Fly Ash	0.2	A	2.43	3.30	0.145	<0.02	<0.05	0.112
0.1/0.1 Cement/Fly Ash	0.2	B	9.13	0.29	1.19	<0.02	<0.05	52.8
0.1/0.3 Cement/Fly Ash	0.2	A	0.587	1.70	0.016	<0.02	<0.05	0.127
0.1/0.3 Cement/Fly Ash	0.2	B	8.38	34.8	0.726	<0.02	<0.05	41.4
0.3/0.1 Cement/Fly Ash	0.2	A	0.618	<0.02	0.01	<0.02	<0.05	<0.02
0.3/0.1 Cement/Fly Ash	0.2	B	0.56	<0.02	<0.02	<0.02	<0.05	<0.02
0.3/0.3 Cement/Fly Ash	0.2	A	0.137	<0.02	<0.02	<0.02	<0.05	<0.02
0.3/0.3 Cement/Fly Ash	0.2	B	0.297	<0.027	<0.02	<0.02	<0.05	<0.02

(Continued)

Table C17 (Concluded)

Binder Ratio	Water Ratio	Replicate	mg/ℓ				
			4A-DNT	2A-DNT	2, 6-DNT	2, 4-DNT	NB
0.1 Cement	0.2	A	<0.02	0.056	<0.02	0.02	ND[1]
0.1 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.3 Cement	0.2	A	0.124	0.067	<0.02	<0.02	ND
0.3 Cement	0.2	B	<0.02	0.028	<0.02	<0.02	ND
0.5 Cement	0.2	A	0.169	0.035	<0.02	<0.02	ND
0.5 Cement	0.2	B	0.134	0.042	<0.02	<0.02	ND
0.7 Cement	0.2	A	0.073	0.015	<0.02	<0.02	ND
0.7 Cement	0.2	B	0.179	0.046	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.2	A	0.01	0.01	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.2	B	<0.02	0.067	<0.02	0.062	ND
0.1/0.3 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.3 Cement/Fly Ash	0.2	B	<0.02	0.03	<0.02	0.027	ND
0.3/0.1 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.1 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND

[1] ND: Denotes that compound was not detected in sample.

Table C18
Results of Explosives for 2-Day TCLP for Detailed Evaluation of Soil 19

Binder Ratio	Water Ratio	Replicate	mg/ℓ HMX	RDX	TNB	DNB	TERTYL	TNT
0.1 Cement	0.2	A	0.025	0.022	0.071	<0.02	<0.05	0.091
0.1 Cement	0.2	B	0.098	0.06	0.10	<0.02	<0.05	1.20
0.3 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02
0.3 Cement	0.2	B	0.391	0.056	0.038	<0.02	<0.05	<0.02
0.5 Cement	0.2	A	0.023	<0.02	<0.02	<0.02	<0.05	<0.02
0.5 Cement	0.2	B	0.108	<0.02	0.015	<0.02	<0.05	<0.02
0.7 Cement	0.2	A	0.026	<0.02	<0.02	<0.02	<0.05	<0.02
0.7 Cement	0.2	B	0.141	<0.02	<0.02	<0.02	<0.05	<0.02
0.1/0.1 Cement/Fly Ash	0.2	A	0.09	0.065	0.079	<0.02	<0.05	1.05
0.1/0.1 Cement/Fly Ash	0.2	B	0.634	0.252	0.551	<0.02	<0.05	11.8
0.1/0.3 Cement/Fly Ash	0.2	A	0.067	0.040	0.043	<0.02	<0.05	0.324
0.1/0.3 Cement/Fly Ash	0.2	B	0.274	0.123	0.183	<0.02	<0.05	2.91
0.3/0.1 Cement/Fly Ash	0.2	A	0.065	0.012	0.059	<0.02	<0.05	<0.02
0.3/0.1 Cement/Fly Ash	0.2	B	0.389	0.035	0.188	<0.02	<0.05	<0.02
0.3/0.3 Cement/Fly Ash	0.2	A	0.01	0.146	0.079	<0.02	<0.05	1.24
0.3/0.3 Cement/Fly Ash	0.2	B	0.355	0.042	0.163	<0.02	<0.05	<0.02

(Continued)

Table C18 (Concluded)

Binder Ratio	Water Ratio	Replicate	mg/ℓ				
			4A-DNT	2A-DNT	2, 6-DNT	2, 4-DNT	NB
0.1 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	ND[1]
0.1 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.3 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.3 Cement	0.2	B	0.021	<0.02	<0.02	<0.02	ND
0.5 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.2	B	0.018	<0.02	<0.02	<0.02	ND
0.7 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.7 Cement	0.2	B	0.021	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.3 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.3 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.1 Cement/Fly Ash	0.2	A	0.012	<0.02	<0.02	<0.02	ND
0.3/0.1 Cement/Fly Ash	0.2	B	0.011	<0.02	<0.02	<0.02	ND
0.3/0.3 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND

[1] ND: Denotes that compound was not detected in sample.

Table C19
Results of Explosives for 2-Day TCLP for Detailed Evaluation of Soil 31

			mg/ℓ					
Binder Ratio	Water Ratio	Replicate	HMX	RDX	TNB	DNB	TERTYL	TNT
0.1 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.1 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.3 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.3 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.5 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.5 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.7 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.7 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.1/0.1 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.1/0.1 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.1/0.3 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.1/0.3 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.3/0.1 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.3/0.1 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.3/0.3 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.3/0.3 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

(Continued)

Table C19 (Concluded)

Binder Ratio	Water Ratio	Replicate	mg/ℓ				
			4A-DNT	2A-DNT	2, 6-DNT	2, 4-DNT	NB
0.1 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	ND[1]
0.1 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.3 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.3 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.7 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.7 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.3 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.3 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.1 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.1 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND

[1] ND: Denotes that compound was not detected in sample.

Table C20
Results for Metals for 14-Day TCLP for Detailed Evaluation of Umatilla Army Depot Soil 2236

Binder Ratio	Water Ratio	Replicate	mg/ℓ								
			As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
0.1 Cement	0.2	A	NA[1]	NA	NA	0.352	NA	0.259	0.381	NA	NA
0.1 Cement	0.2	B	NA	NA	NA	0.744	NA	0.404	0.453	NA	NA
0.3 Cement	0.2	A	NA	NA	NA	0.401	NA	0.186	0.480	NA	NA
0.3 Cement	0.2	B	NA	NA	NA	0.897	NA	0.235	0.186	NA	NA
0.5 Cement	0.2	A	NA	NA	NA	0.397	NA	0.067	0.149	NA	NA
0.5 Cement	0.2	B	NA	NA	NA	0.847	NA	0.117	0.159	NA	NA
0.7 Cement	0.2	A	NA	NA	NA	0.071	NA	<0.05	<0.10	NA	NA
0.7 Cement	0.2	B	NA	NA	NA	0.236	NA	<0.05	<0.10	NA	NA
0.1/0.1 Cement/Fly Ash	0.2	A	NA	NA	NA	0.545	NA	0.297	0.611	NA	NA
0.1/0.1 Cement/Fly Ash	0.2	B	NA	NA	NA	1.29	NA	0.447	0.303	NA	NA
0.1/0.3 Cement/Fly Ash	0.2	A	NA	NA	NA	0.409	NA	0.171	0.555	NA	NA
0.1/0.3 Cement/Fly Ash	0.2	B	NA	NA	NA	0.859	NA	0.254	0.312	NA	NA
0.3/0.1 Cement/Fly Ash	0.2	A	NA	NA	NA	0.383	NA	0.109	1.13	NA	NA
0.3/0.1 Cement/Fly Ash	0.2	B	NA	NA	NA	0.948	NA	0.169	0.428	NA	NA
0.3/0.3 Cement/Fly Ash	0.2	A	NA	NA	NA	0.353	NA	0.086	0.336	NA	NA
0.3/0.3 Cement/Fly Ash	0.2	B	NA	NA	NA	0.390	NA	0.097	0.374	NA	NA

[1] NA: Denotes sample was not analyzed for this compound.

Table C21
Results for Metals for 14-Day TCLP for Umatilla Army Depot, Soil 15

Binder Ratio	Water Ratio	Replicate	mg/ℓ								
			As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
0.1 Cement	0.2	A	<0.20	3.99	<0.01	0.103	<0.05	0.106	<0.10	<0.10	0.003
0.1 Cement	0.2	B	<0.20	5.39	<0.01	0.185	<0.05	0.203	<0.10	<0.10	0.003
0.3 Cement	0.2	A	<0.20	1.83	<0.01	<0.01	<0.05	0.142	<0.10	<0.10	0.003
0.3 Cement	0.2	B	<0.20	0.785	<0.01	<0.01	<0.05	0.068	<0.10	<0.10	<0.003
0.5 Cement	0.2	A	<0.20	1.52	<0.01	<0.01	<0.05	0.062	<0.10	<0.10	<0.003
0.5 Cement	0.2	B	<0.20	1.88	<0.01	<0.01	<0.05	<0.05	<0.10	<0.10	<0.003
0.7 Cement	0.2	A	<0.20	1.70	<0.01	<0.01	<0.05	0.075	<0.10	<0.10	<0.003
0.7 Cement	0.2	B	<0.20	2.12	<0.01	<0.01	<0.05	0.083	<0.10	<0.10	<0.003
0.1/0.1 Cement/Fly Ash	0.2	A	<0.20	5.56	<0.01	0.341	<0.05	0.110	<0.10	<0.10	<0.003
0.1/0.1 Cement/Fly Ash	0.2	B	<0.20	2.75	<0.01	0.043	<0.05	0.068	<0.10	<0.10	<0.003
0.1/0.3 Cement/Fly Ash	0.2	A	<0.20	1.81	<0.01	0.283	<0.05	<0.05	0.392	<0.10	<0.003
0.1/0.3 Cement/Fly Ash	0.2	B	<0.20	3.79	<0.01	0.114	<0.05	0.071	0.104	<0.10	<0.003
0.3/0.1 Cement/Fly Ash	0.2	A	<0.20	2.42	<0.01	<0.01	<0.05	0.332	<0.10	<0.10	<0.003
0.3/0.1 Cement/Fly Ash	0.2	B	<0.20	2.72	<0.01	<0.01	<0.05	<0.05	<0.10	<0.10	<0.003
0.3/0.3 Cement/Fly Ash	0.2	A	<0.20	2.55	<0.01	0.064	<0.05	<0.05	<0.10	<0.10	0.004
0.3/0.3 Cement/Fly Ash	0.2	B	<0.20	3.03	<0.01	0.047	<0.05	<0.05	<0.10	<0.10	0.004

Table C22
Results for Metals for 14-Day TCLP for Umatilla Army Depot Soil 19

Binder Ratio	Water Ratio	Replicate	mg/ℓ								
			As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
0.1 Cement	0.2	A	<0.20	8.26	NA[1]	0.553	NA	<0.05	15.3	1.35	NA
0.1 Cement	0.2	B	<0.20	6.74	NA	0.697	NA	<0.05	5.56	0.410	NA
0.3 Cement	0.2	A	<0.20	5.81	NA	0.130	NA	<0.05	0.192	0.200	NA
0.3 Cement	0.2	B	<0.20	3.83	NA	<0.01	NA	<0.05	<0.10	0.227	NA
0.5 Cement	0.2	A	<0.20	2.81	NA	<0.01	NA	0.108	0.424	<0.10	NA
0.5 Cement	0.2	B	<0.20	2.80	NA	<0.01	NA	0.051	<0.10	<0.10	NA
0.7 Cement	0.2	A	<0.20	1.91	NA	<0.01	NA	0.104	1.00	<0.10	NA
0.7 Cement	0.2	B	<0.20	2.40	NA	<0.01	NA	<0.05	<0.10	0.121	NA
0.1/0.1 Cement/Fly Ash	0.2	A	<0.20	3.92	NA	0.682	NA	<0.05	3.17	<0.10	NA
0.1/0.1 Cement/Fly Ash	0.2	B	<0.20	5.39	NA	0.814	NA	<0.05	5.39	4.235	NA
0.1/0.3 Cement/Fly Ash	0.2	A	<0.20	4.21	NA	0.127	NA	<0.05	4.21	<0.104	NA
0.1/0.3 Cement/Fly Ash	0.2	B	<0.20	1.77	NA	<0.01	NA	0.134	1.77	0.133	NA
0.3/0.1 Cement/Fly Ash	0.2	A	<0.20	3.96	NA	1.50	NA	<0.05	3.96	<0.10	NA
0.3/0.1 Cement/Fly Ash	0.2	B	<0.20	4.49	NA	1.64	NA	<0.05	4.49	<0.10	NA
0.3/0.3 Cement/Fly Ash	0.2	A	<0.20	4.64	NA	0.676	NA	<0.05	4.64	<0.10	NA
0.3/0.3 Cement/Fly Ash	0.2	B	<0.20	5.64	NA	0.388	NA	<0.05	5.64	<0.10	NA

[1] NA: Denotes that sample was not analyzed for this compound.

Table C23
Results of Metals for 14-Day TCLP for Umatilla Army Depot Soil 31

Binder Ratio	Water Ratio	Replicate	mg/ℓ								
			As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
0.1 Cement	0.2	A	<0.02	NA[1]	NA	<0.01	NA	0.057	<0.10	NA	NA
0.1 Cement	0.2	B	<0.02	NA	NA	<0.01	NA	0.074	<0.10	NA	NA
0.3 Cement	0.2	A	<0.02	NA	NA	<0.01	NA	0.083	<0.10	NA	NA
0.3 Cement	0.2	B	<0.02	NA	NA	<0.01	NA	0.087	<0.10	NA	NA
0.5 Cement	0.2	A	<0.02	NA	NA	<0.01	NA	0.052	<0.10	NA	NA
0.5 Cement	0.2	B	<0.02	NA	NA	<0.01	NA	0.056	<0.10	NA	NA
0.7 Cement	0.2	A	<0.02	NA	NA	<0.01	NA	0.077	<0.10	NA	NA
0.7 Cement	0.2	B	<0.02	NA	NA	<0.01	NA	0.052	<0.10	NA	NA
0.1/0.1 Cement/Fly Ash	0.2	A	<0.02	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.1/0.1 Cement/Fly Ash	0.2	B	<0.02	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.1/0.3 Cement/Fly Ash	0.2	A	<0.02	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.1/0.3 Cement/Fly Ash	0.2	B	<0.02	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.3/0.1 Cement/Fly Ash	0.2	A	<0.02	NA	NA	<0.01	NA	0.065	<0.10	NA	NA
0.3/0.1 Cement/Fly Ash	0.2	B	<0.02	NA	NA	<0.01	NA	0.051	<0.10	NA	NA
0.3/0.3 Cement/Fly Ash	0.2	A	<0.02	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA
0.3/0.3 Cement/Fly Ash	0.2	B	<0.02	NA	NA	<0.01	NA	<0.05	<0.10	NA	NA

[1] NA: Denotes that sample was not analyzed for this compound.

Table C24
Results of Explosives for 14-Day TCLP for Detailed Evaluation of Soil 15

			mg/ℓ					
Binder Ratio	Water Ratio	Replicate	HMX	RDX	TNB	DNB	TERTYL	TNT
0.1 Cement	0.2	A	4.32	8.66	0.113	<0.02	<0.05	2.86
0.1 Cement	0.2	B	6.51	29.2	0.242	<0.02	<0.05	17.2
0.3 Cement	0.2	A	1.87	2.94	0.044	<0.02	<0.05	0.499
0.3 Cement	0.2	B	5.55	21.0	0.344	<0.02	<0.05	0.180
0.5 Cement	0.2	A	0.771	1.74	0.025	<0.02	<0.05	0.230
0.5 Cement	0.2	B	4.80	16.2	0.119	<0.02	<0.05	0.071
0.7 Cement	0.2	A	0.549	0.791	0.017	<0.02	<0.05	0.087
0.7 Cement	0.2	B	0.582	0.217	0.010	<0.02	<0.05	<0.02
0.1/0.1 Cement/Fly Ash	0.2	A	1.96	1.83	0.086	<0.02	<0.05	1.12
0.1/0.1 Cement/Fly Ash	0.2	B	7.92	50.7	0.653	<0.02	<0.05	63.8
0.1/0.3 Cement/Fly Ash	0.2	A	0.240	0.508	<0.02	<0.02	<0.05	0.025
0.1/0.3 Cement/Fly Ash	0.2	B	7.32	54.3	0.311	<0.02	<0.05	30.9
0.3/0.1 Cement/Fly Ash	0.2	A	0.322	0.623	0.028	<0.02	<0.05	0.300
0.3/0.1 Cement/Fly Ash	0.2	B	0.365	0.915	0.023	<0.02	<0.05	0.290
0.3/0.3 Cement/Fly Ash	0.2	A	0.098	0.216	<0.02	<0.02	<0.05	<0.02
0.3/0.3 Cement/Fly Ash	0.2	B	0.170	0.523	<0.02	<0.02	<0.05	0.022

(Continued)

Table C24 (Concluded)

Binder Ratio	Water Ratio	Replicate	mg/ℓ				
			4A-DNT	2A-DNT	2, 6-DNT	2, 4-DNT	NB
0.1 Cement	0.2	A	0.361	0.061	<0.02	<0.02	ND[1]
0.1 Cement	0.2	B	0.041	0.014	<0.02	<0.02	ND
0.3 Cement	0.2	A	0.302	0.034	<0.02	<0.02	ND
0.3 Cement	0.2	B	0.115	0.021	<0.02	<0.02	ND
0.5 Cement	0.2	A	0.115	0.012	<0.02	<0.02	ND
0.5 Cement	0.2	B	0.078	0.016	<0.02	<0.02	ND
0.7 Cement	0.2	A	0.054	<0.02	<0.02	<0.02	ND
0.7 Cement	0.2	B	0.068	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.2	A	0.027	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.3 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.3 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.1 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.1 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND

[1] ND: Denotes that compound was not detected in sample.

Table C25
Results of Explosives for 14-Day TCLP for Detailed Evaluation of Soil 19

Binder Ratio	Water Ratio	Replicate	mg/ℓ					
			HMX	RDX	TNB	DNB	TERTYL	TNT
0.1 Cement	0.2	A	0.013	0.066	<0.02	<0.02	<0.05	0.049
0.1 Cement	0.2	B	0.095	0.176	0.071	<0.02	<0.05	1.04
0.3 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.05	0.063
0.3 Cement	0.2	B	0.095	0.186	0.079	<0.02	<0.05	3.40
0.5 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02
0.5 Cement	0.2	B	0.081	0.161	0.070	<0.02	<0.05	1.32
0.7 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02
0.7 Cement	0.2	B	0.141	0.136	0.076	<0.02	<0.05	8.73
0.1/0.1 Cement/Fly Ash	0.2	A	0.105	0.180	0.047	<0.02	<0.05	0.470
0.1/0.1 Cement/Fly Ash	0.2	B	0.720	0.213	0.376	<0.02	<0.05	8.25
0.1/0.3 Cement/Fly Ash	0.2	A	0.030	0.015	0.018	<0.02	<0.05	0.036
0.1/0.3 Cement/Fly Ash	0.2	B	0.614	0.126	0.323	<0.02	<0.05	4.08
0.3/0.1 Cement/Fly Ash	0.2	A	0.019	0.014	0.039	<0.02	<0.05	0.299
0.3/0.1 Cement/Fly Ash	0.2	B	0.244	0.027	0.069	<0.02	<0.05	0.019
0.3/0.3 Cement/Fly Ash	0.2	A	0.025	0.047	0.042	<0.02	<0.05	0.624
0.3/0.3 Cement/Fly Ash	0.2	B	0.113	0.071	0.107	<0.02	<0.05	3.09

(Continued)

Table C25 (Concluded)

Binder Ratio	Water Ratio	Replicate	mg/ℓ				
			4A-DNT	2A-DNT	2, 6-DNT	2, 4-DNT	NB
0.1 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	ND[1]
0.1 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.3 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.3 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.7 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.7 Cement	0.2	B	0.036	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.3 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.3 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.1 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.1 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND

[1] ND: Denotes that compound was not detected in sample.

Table C26
Results of Explosives for 14-Day TCLP for Detailed Evaluation of Soil 31

			mg/ℓ					
Binder Ratio	Water Ratio	Replicate	HMX	RDX	TNB	DNB	TERTYL	TNT
0.1 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02
0.1 Cement	0.2	B	0.17	0.08	<0.02	<0.02	<0.05	<0.02
0.3 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02
0.3 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02
0.5 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02
0.5 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02
0.7 Cement	0.2	A	4.44	0.659	0.042	<0.02	<0.05	<0.02
0.7 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02
0.1/0.1 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02
0.1/0.1 Cement/Fly Ash	0.2	B	0.022	0.085	<0.02	<0.02	<0.05	<0.02
0.1/0.3 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02
0.1/0.3 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02
0.3/0.1 Cement/Fly Ash	0.2	A	<0.02	0.157	<0.02	<0.02	<0.05	<0.02
0.3/0.1 Cement/Fly Ash	0.2	B	<0.02	0.068	<0.02	0.02	<0.05	<0.02
0.3/0.3 Cement/Fly Ash	0.2	A	<0.02	0.033	<0.02	<0.02	<0.05	<0.02
0.3/0.3 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02

(Continued)

Table C26 (Concluded)

Binder Ratio	Water Ratio	Replicate	mg/ℓ				
			4A-DNT	2A-DNT	2, 6-DNT	2, 4-DNT	NB
0.1 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	ND[1]
0.1 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.3 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.3 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.5 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.7 Cement	0.2	A	0.141	<0.02	<0.02	<0.02	ND
0.7 Cement	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.1 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.3 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.1/0.3 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.1 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.1 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3 Cement/Fly Ash	0.2	A	<0.02	<0.02	<0.02	<0.02	ND
0.3/0.3 Cement/Fly Ash	0.2	B	<0.02	<0.02	<0.02	<0.02	ND

[1] ND: Denotes that compound was not detected in sample.

Appendix D
Results of Additional Studies of Soil 15 and Soil 19 From Umatilla Army Depot

Table D1
Results for Metals for Bulk Chemistry for Untreated Umatilla Army Depot Soils 15/31 and 19/31

Soil	Replicate	mg/kg								
		As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
100% 15	A	13.3	270	0.23	41	13	54	160	20	77
100% 15	B	7.7	280	0.19	33	9.9	80	340	13	47
100% 15	C	11.4	640	0.20	62	12	88	1,000	24	71
75% 15/25% 31	A	4.5	380	0.23	30	10	74	200	14	35
75% 15/25% 31	B	3.8	270	0.18	25	9.8	92	240	24	55
75% 15/25% 31	C	7.9	270	0.20	27	11	83	220	16	60
50% 15/50% 31	A	3.8	270	0.20	24	13	94	320	42	138
50% 15/50% 31	B	4.6	260	0.22	19	9.9	54	160	11	43
50% 15/50% 31	C	8.9	260	0.20	23	9.3	48	210	9.4	16
25% 15/75% 31	A	3.3	160	0.22	10	9.4	35	170	6.8	19
25% 15/75% 31	B	2.9	180	0.20	11	9.4	41	160	13	8.4
25% 15/75% 31	C	4.0	200	0.21	9.0	8.0	33	100	8.4	9.1
100% 19	A	8.3	2,200	0.18	56	3.6	18	4,000	8.0	10
100% 19	B	6.9	2,300	0.22	75	7.8	16	8,300	120	12
100% 19	C	8.7	2,900	0.20	64	7.6	16	10,000	150	12
75% 19/25% 31	A	16.4	2,100	0.19	110	7.6	25	5,200	57	29
75% 19/25% 31	B	9.4	4,100	0.19	45	8.5	15	4,800	74	12
75% 19/25% 31	C	5.7	2,400	0.15	98	8.0	20	6,400	130	21
50% 19/50% 31	A	4.8	1,200	0.17	32	8.6	14	2,700	56	23
50% 19/50% 31	B	<4.0	1,400	0.18	32	8.0	14	3,800	81	17
50% 19/50% 31	C	3.2	2,200	0.21	38	8.8	16	1,700	43	20
25% 19/75% 31	A	3.3	840	0.19	17	7.6	10	1,600	28	12
25% 19/75% 31	B	3.3	640	0.18	13	7.5	10	3,700	43	21
25% 19/75% 31	C	2.4	1,200	0.21	17	8.6	13	2,200	26	26

Table D2
Results for Explosives for Bulk Chemistry for Untreated Umatilla Army Depot Soils 15/31 and 19/31

Soil	Replicate	mg/kg										
		HMX	RDX	TNB	DNB	TETRYL	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT	NB
100% 15	A	588	3,740	40.0	<25.0	<65.0	4,910	<25.0	<25.0	<26.0	<25.0	ND[1]
100% 15	B	640	4,020	40.0	<25.0	<65.0	5,310	<25.0	<25.0	<26.0	<25.0	ND
100% 15	C	600	3,840	38.5	<25.0	<65.0	4,890	<25.0	<25.0	<26.0	<25.0	ND
75% 15/25% 31	A	424	2,710	28.5	<25.0	<65.0	3,420	<25.0	<25.0	<26.0	<25.0	ND
75% 15/25% 31	B	592	3,520	35.0	<25.0	<65.0	6,420	<25.0	<25.0	<26.0	<25.0	ND
75% 15/25% 31	C	464	2,940	29.5	<25.0	<65.0	3,690	<25.0	<25.0	<26.0	<25.0	ND
50% 15/50% 31	A	298	1,880	19.0	<25.0	<65.0	2,430	<25.0	<25.0	<26.0	<25.0	ND
50% 15/50% 31	B	304	1,930	18.5	<25.0	<65.0	2,400	<25.0	<25.0	<26.0	<25.0	ND
50% 15/50% 31	C	398	2,400	23.0	<25.0	<65.0	3,780	<25.0	<25.0	<26.0	<25.0	ND
25% 15/75% 31	A	161	988	10.0	<25.0	<65.0	1,320	<25.0	<25.0	<26.0	<25.0	ND
25% 15/75% 31	B	178	1,080	11.5	<25.0	<65.0	1,570	<25.0	<25.0	<26.0	<25.0	ND
25% 15/75% 31	C	166	1,040	9.5	<25.0	<65.0	1,500	<25.0	<25.0	<26.0	<25.0	ND
100% 19	A	3.68	7.71	14.5	0.150	<0.65	69.8	0.745	0.565	<26.0	0.155	ND
100% 19	B	3.46	6.76	15.2	0.160	<0.65	51.6	0.810	0.615	<26.0	0.140	ND

(Continued)

[1] ND = Not detected.

Table D2 (Concluded)

Soil	Replicate	mg/kg										
		HMX	RDX	TNB	DNB	TETRYL	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT	NB
100% 19	C	4.52	143	17.7	0.170	<0.65	171	0.835	0.570	<26.0	0.170	ND
75% 19/25% 31	A	2.76	5.11	11.4	0.125	<0.65	38.3	0.715	0.505	<26.0	0.280	ND
75% 19/25% 31	B	2.51	5.36	14.3	0.135	<0.65	678	0.215	0.160	<26.0	0.155	ND
75% 19/25% 31	C	3.06	7.00	12.7	0.125	<0.65	50.3	0.740	0.510	<26.0	0.125	ND
50% 19/50% 31	A	1.80	3.84	7.20	0.075	<0.65	28.0	0.625	0.395	<26.0	0.050	ND
50% 19/50% 31	B	2.09	4.22	8.64	0.095	<0.65	140	0.745	0.440	<26.0	0.110	ND
50% 19/50% 31	C	1.72	4.24	8.20	0.105	<0.65	36.4	0.675	0.490	<26.0	0.065	ND
25% 19/75% 31	A	0.935	2.54	4.02	0.055	<0.65	17.9	0.690	0.350	<26.0	<0.25	ND
25% 19/75% 31	B	1.45	3.06	4.58	0.085	<0.65	38.1	0.815	0.455	<26.0	0.080	ND
25% 19/75% 31	C	1.02	2.26	3.82	0.055	<0.65	14.7	0.635	0.345	<26.0	0.050	ND

Table D3
Results for Toxicity Characteristic Leaching Procedure (TCLP) for Metals for Untreated Umatilla Army Depot Soils 15/31 and 19/31

Soil	Replicate	mg/kg								
		As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
100% 15	A	0.004	8.28	<0.002	0.758	0.058	0.036	0.764	0.026	<0.004
100% 15	B	0.005	8.28	<0.002	0.748	0.052	0.068	0.742	0.024	<0.004
100% 15	C	0.005	8.08	<0.002	0.764	0.046	0.056	0.706	0.017	<0.004
75% 15/25% 31	A	<0.004	11.2	<0.002	0.232	0.058	0.024	0.024	0.008	<0.004
75% 15/25% 31	B	<0.004	11.5	<0.002	0.256	0.032	0.032	0.032	0.010	<0.004
75% 15/25% 31	C	<0.004	11.4	<0.002	0.202	0.042	0.022	0.022	0.009	<0.004
50% 15/50% 31	A	<0.004	4.36	<0.002	0.296	0.042	0.024	0.204	0.010	<0.004
50% 15/50% 31	B	<0.004	4.68	<0.002	0.278	0.066	<0.016	0.182	<0.006	<0.004
50% 15/50% 31	C	0.004	4.52	<0.002	0.270	0.054	<0.016	0.150	0.006	<0.004
25% 15/75% 31	A	<0.004	2.46	<0.002	0.152	<0.030	<0.016	0.132	0.011	<0.004
25% 15/75% 31	B	<0.004	2.04	<0.002	0.158	0.060	<0.016	0.134	0.010	<0.004
25% 15/75% 31	C	0.004	2.12	<0.002	0.082	0.034	<0.016	0.102	<0.006	<0.004
100% 19	A	0.016	16.1	<0.002	1.90	<0.030	<0.006	12.1	1.46	<0.004
100% 19	B	0.018	15.8	<0.002	1.91	<0.030	<0.016	11.6	1.44	<0.004
100% 19	C	0.018	15.3	<0.002	1.34	<0.030	0.020	10.9	1.34	<0.004
75% 19/25% 31	A	0.029	14.8	<0.002	1.57	<0.030	<0.016	30.4	1.22	<0.004
75% 19/25% 31	B	0.030	14.6	<0.002	1.51	<0.030	<0.016	29.8	1.20	<0.004
75% 19/25% 31	C	0.028	14.6	<0.002	1.58	0.054	<0.016	30.8	1.16	<0.004
50% 19/50% 31	A	0.010	11.3	<0.002	1.24	<0.030	<0.016	51.0	1.33	<0.004
50% 19/50% 31	B	0.010	10.9	<0.002	1.25	0.030	0.024	50.2	1.39	<0.004
50% 19/50% 31	C	0.010	11.8	<0.002	1.23	0.032	<0.016	51.4	1.31	<0.004
25% 19/75% 31	A	0.008	6.84	<0.002	0.844	0.032	0.024	27.0	0.514	<0.004
25% 19/75% 31	B	0.010	7.01	<0.002	0.796	0.032	<0.016	27.2	0.514	<0.004
25% 19/75% 31	C	0.009	7.26	<0.002	0.866	0.054	<0.016	26.6	0.492	<0.004

Table D4
Results for Explosives for TCLP for Untreated Umatilla Army Depot Soils 15/31 and 19/31

Soil	Replicate	mg/kg										
		HMX	RDX	TNB	DNB	TETRYL	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT	NB
100% 15	A	6.31	33.9	0.452	<0.020	<0.050	30.5	0.894	0.989	<0.020	0.017	ND[1]
100% 15	B	6.26	33.4	0.446	<0.020	<0.050	30.0	0.921	0.998	<0.020	<0.020	ND
100% 15	C	6.36	34.1	0.451	<0.020	<0.050	30.5	0.936	1.02	<0.020	<0.020	ND
75% 15/25% 31	A	5.82	32.4	0.247	<0.020	<0.050	22.5	0.946	1.05	<0.020	<0.020	ND
75% 15/25% 31	B	5.80	32.3	0.245	<0.020	<0.050	22.5	0.949	1.04	<0.020	<0.020	ND
75% 15/25% 31	C	5.81	32.4	0.246	<0.020	<0.050	22.5	0.952	1.06	<0.020	<0.020	ND
50% 15/50% 31	A	4.59	30.6	0.224	<0.020	<0.050	24.6	0.810	1.05	<0.020	<0.020	ND
50% 15/50% 31	B	4.60	30.6	0.224	<0.020	<0.050	24.6	0.807	1.04	<0.020	<0.020	ND
50% 15/50% 31	C	4.70	31.1	0.220	<0.020	<0.050	24.9	0.816	1.03	<0.020	<0.020	ND
25% 15/75% 31	A	3.22	29.9	0.220	<0.020	<0.050	29.4	0.437	0.456	<0.020	<0.020	ND
25% 15/75% 31	B	3.06	29.7	0.206	<0.020	<0.050	28.2	0.402	0.431	<0.020	<0.020	ND
25% 15/75% 31	C	3.19	30.0	0.208	<0.020	<0.050	29.7	0.424	0.444	<0.020	<0.020	ND
100% 19	A	0.070	0.107	0.112	<0.020	<0.050	0.696	0.013	<0.020	<0.020	<0.020	ND
100% 19	B	0.070	0.101	0.113	<0.020	<0.050	0.687	0.014	<0.020	<0.020	<0.020	ND

(Continued)

[1] ND = Not detected.

Table D4 (Concluded)

Soil	Replicate	mg/kg										
		HMX	RDX	TNB	DNB	TETRYL	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT	NB
100% 19	C	0.073	0.107	0.112	<0.020	<0.050	0.697	0.012	<0.020	<0.020	<0.020	ND
75% 19/25% 31	A	0.062	0.113	0.102	<0.020	<0.050	0.913	<0.020	<0.020	<0.020	<0.020	ND
75% 19/25% 31	B	0.063	0.114	0.104	<0.020	<0.050	0.929	<0.020	<0.020	<0.020	<0.020	ND
75% 19/25% 31	C	0.064	0.113	0.106	<0.020	<0.050	0.921	<0.020	<0.020	<0.020	<0.020	ND
50% 19/50% 31	A	0.039	0.063	0.076	<0.020	<0.050	0.590	<0.020	<0.020	<0.020	<0.020	ND
50% 19/50% 31	B	0.039	0.066	0.078	<0.020	<0.050	0.629	<0.020	<0.020	<0.020	<0.020	ND
50% 19/50% 31	C	0.038	0.065	0.078	<0.020	<0.050	0.624	<0.020	<0.020	<0.020	<0.020	ND
25% 19/75% 31	A	0.026	0.059	0.036	<0.020	<0.050	0.291	<0.020	<0.020	<0.020	<0.020	ND
25% 19/75% 31	B	0.029	0.060	0.036	<0.020	<0.050	0.291	<0.020	<0.020	<0.020	<0.020	ND
25% 19/75% 31	C	0.027	0.063	0.036	<0.020	<0.050	0.290	<0.020	<0.020	<0.020	<0.020	ND

Table D5
Results for TCLP for Metals for Treated Umatilla Army Depot Soils 15/31 and 19/31

Soil	Replicate	mg/kg								
		As	Ba	Be	Cd	Co	Cr	Pb	Sb	Tl
0.3 Cement/0.1 Fly Ash										
100% 15	A	0.007	1.71	<0.002	<0.07	<0.03	0.044	<0.080	<0.006	<0.004
100% 15	B	0.004	1.75	<0.002	1.38	<0.03	0.054	0.082	<0.006	<0.004
100% 15	C	<0.004	1.54	<0.002	1.24	<0.03	0.044	<0.080	<0.006	<0.004
75% 15/25% 31	A	<0.004	1.60	<0.002	1.24	<0.03	0.028	0.082	<0.006	<0.004
75% 15/25% 31	B	<0.004	1.61	<0.002	1.19	<0.03	0.074	<0.080	<0.006	<0.004
75% 15/25% 31	C	<0.004	1.58	<0.002	1.14	<0.03	0.068	<0.080	<0.006	<0.004
50% 15/50% 31	A	<0.004	1.32	<0.002	1.11	<0.03	0.090	<0.080	<0.006	0.005
50% 15/50% 31	B	<0.004	1.26	<0.002	1.55	<0.03	0.078	0.082	<0.006	<0.004
50% 15/50% 31	C	<0.004	1.82	<0.002	1.71	<0.03	0.046	<0.080	<0.006	<0.004
25% 15/75% 31	A	<0.004	1.61	<0.002	1.42	<0.03	0.116	<0.080	<0.006	<0.004
25% 15/75% 31	B	<0.004	1.31	<0.002	1.90	<0.03	0.112	<0.080	<0.006	<0.004
25% 15/75% 31	C	<0.004	1.24	<0.002	2.08	<0.03	0.098	<0.080	<0.006	<0.004
100% 19	A	<0.004	1.45	<0.002	3.54	<0.03	0.072	<0.080	0.047	<0.004
100% 19	B	<0.004	1.30	<0.002	<0.007	<0.03	0.166	<0.080	0.037	<0.004
100% 19	C	<0.004	1.83	<0.002	<0.007	<0.03	0.096	<0.080	0.060	<0.004
75% 19/25% 31	A	<0.004	1.56	<0.002	<0.007	<0.03	0.050	<0.080	0.012	<0.004
75% 19/25% 31	B	<0.004	1.61	<0.002	<0.007	<0.03	0.086	<0.080	0.017	<0.004
75% 19/25% 31	C	<0.004	1.55	<0.002	<0.007	<0.03	0.064	<0.080	0.016	<0.004
50% 19/50% 31	A	<0.004	2.25	<0.002	<0.007	<0.03	0.066	<0.080	0.009	<0.004
50% 19/50% 31	B	<0.004	2.35	<0.002	<0.007	<0.03	0.068	<0.080	0.007	<0.004
50% 19/50% 31	C	<0.004	2.34	<0.002	<0.007	<0.03	0.066	<0.080	<0.001	<0.004
25% 19/75% 31	A	<0.004	1.80	<0.002	<0.007	<0.03	0.104	<0.080	<0.006	<0.004
25% 19/75% 31	B	<0.004	1.76	<0.002	0.10	<0.03	0.074	<0.080	0.011	<0.004
25% 19/75% 31	C	<0.004	1.60	<0.002	<0.007	<0.03	0.070	<0.080	0.010	<0.004

Table D6
Results for Explosives for TCLP for Treated Umatilla Army Depot Soils 15/31 and 19/31

Soil	Replicate	mg/kg										
		HMX	RDX	TNB	DNB	TETRYL	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT	NB
0.3 Cement/0.1 Fly ash												
100% 15	A	3.53	25.9	0.520	<0.020	<0.050	0.499	0.168	0.067	<0.020	<0.020	ND[1]
100% 15	B	3.42	25.4	0.433	<0.020	<0.050	0.376	0.150	0.055	<0.020	<0.020	ND
100% 15	C	3.47	17.0	0.417	<0.020	<0.050	<0.020	0.181	0.066	<0.020	<0.020	ND
75% 15/25% 31	A	3.36	16.1	0.206	<0.020	<0.050	<0.020	0.130	0.043	<0.020	<0.020	ND
75% 15/25% 31	B	3.42	6.48	0.172	<0.020	<0.050	<0.020	0.101	0.031	<0.020	<0.020	ND
75% 15/25% 31	C	3.42	12.6	0.201	<0.020	<0.050	<0.020	0.117	0.040	<0.020	<0.020	ND
50% 15/50% 31	A	3.28	12.2	0.163	<0.020	<0.050	<0.020	0.085	0.026	<0.020	<0.020	ND
50% 15/50% 31	B	3.38	10.6	0.155	<0.020	<0.050	<0.020	0.079	0.021	<0.020	<0.020	ND
50% 15/50% 31	C	3.35	5.61	0.116	<0.020	<0.050	<0.020	0.078	0.024	<0.020	<0.020	ND
25% 15/75% 31	A	2.45	1.55	0.037	<0.020	<0.050	<0.020	0.051	<0.020	<0.020	<0.020	ND
25% 15/75% 31	B	2.68	1.35	0.049	<0.020	<0.050	<0.020	0.058	0.013	<0.020	<0.020	ND
25% 15/75% 31	C	2.42	0.696	0.030	<0.020	<0.050	<0.020	0.055	0.012	<0.020	<0.020	ND
100% 19	A	0.031	<0.020	0.020	<0.020	<0.050	0.024	0.010	<0.020	<0.020	<0.020	ND

(Continued)

[1] ND = Not detected.

Table D6 (Concluded)

Soil	Replicate	mg/kg										
		HMX	RDX	TNB	DNB	TETRYL	TNT	4A-DNT	2A-DNT	2,6-DNT	2,4-DNT	NB
0.3 Cement/0.1 Fly ash												
100% 19	B	0.036	<0.020	0.019	<0.020	<0.050	0.020	<0.020	<0.020	<0.020	<0.020	ND
100% 19	C	0.028	<0.020	0.024	<0.020	<0.050	0.026	0.010	<0.020	<0.020	<0.020	ND
75% 19/25% 31	A	<0.020	<0.020	<0.020	<0.020	<0.050	<0.020	<0.020	<0.020	<0.020	<0.020	ND
75% 19/25% 31	B	<0.020	<0.020	<0.020	<0.020	<0.050	<0.020	<0.020	<0.020	<0.020	<0.020	ND
75% 19/25% 31	C	<0.020	<0.020	<0.020	<0.020	<0.050	<0.020	<0.020	<0.020	<0.020	<0.020	ND
50% 19/50% 31	A	<0.020	<0.020	<0.020	<0.020	<0.050	<0.020	<0.020	<0.020	<0.020	<0.020	ND
50% 19/50% 31	B	0.032	<0.020	<0.020	<0.020	<0.050	<0.020	<0.020	<0.020	<0.020	<0.020	ND
50% 19/50% 31	C	<0.020	<0.020	<0.020	<0.020	<0.050	<0.020	<0.020	<0.020	<0.020	<0.020	ND
25% 19/75% 31	A	<0.020	<0.020	<0.020	<0.020	<0.050	<0.020	<0.020	<0.020	<0.020	<0.020	ND
25% 19/75% 31	B	<0.020	<0.020	<0.020	<0.020	<0.050	<0.020	<0.020	<0.020	<0.020	<0.020	ND
25% 19/75% 31	C	<0.020	<0.020	<0.020	<0.020	<0.050	0.015	<0.020	<0.020	<0.020	<0.020	ND

Appendix E
Results of Carbon Addition for Solidification/Stabilization of Soil 15

Table E1
Results of Metals for Bulk Chemistry for Phase III Treatment of Soil 15

Soil Mixture	Replicate	Cadmium, mg/kg	Lead, mg/kg
100% Soil 15	A	41.0	160
100% Soil 15	B	33.0	340
100% Soil 15	C	62.0	1,000
75% Soil 15/25% Soil 31	A	30.0	200
75% Soil 15/25% Soil 31	B	25.0	240
75% Soil 15/25% Soil 31	C	27.0	220
50% Soil 15/50% Soil 31	A	24.0	320
50% Soil 15/50% Soil 31	B	19.0	160
50% Soil 15/50% Soil 31	C	23.0	210

Table E2
Results of Explosives for Bulk Chemistry for Phase III Treatment of Soil 15

Soil Mixture	Replicate	mg/kg			
		HMX	RDX	TNB	TNT
100% Soil 15	A	588	3,740	40.0	4,910
100% Soil 15	B	640	4,020	40.0	5,310
100% Soil 15	C	600	3,840	38.5	4,890
75% Soil 15/25% Soil 31	A	424	2,710	28.5	3,420
75% Soil 15/25% Soil 31	B	592	3,520	35.0	6,420
75% Soil 15/25% Soil 31	C	464	2,940	29.5	3,690
50% Soil 15/50% Soil 31	A	298	1,880	19.0	2,430
50% Soil 15/50% Soil 31	B	304	1,930	18.5	2,400
50% Soil 15/50% Soil 31	C	398	2,400	23.0	3,780

Table E3
Results for Toxicity Characteristic Leaching Procedure (TCLP) for Metals for Phase III Untreated Soil 15

Soil Mixture	Replicate	Cadmium, mg/ℓ	Lead, mg/ℓ
100% Soil 15	A	0.758	0.764
100% Soil 15	B	0.748	0.742
100% Soil 15	C	0.764	0.706
75% Soil 15/25% Soil 31	A	0.232	0.024
75% Soil 15/25% Soil 31	B	0.256	0.032
75% Soil 15/25% Soil 31	C	0.202	0.022
50% Soil 15/50% Soil 31	A	0.296	0.204
50% Soil 15/50% Soil 31	B	0.278	0.182
50% Soil 15/50% Soil 31	C	0.270	0.150

Table E4
Results for Explosives for TCLP for Phase III Untreated Soil 15

Soil Mixture	Replicate	mg/ℓ HMX	RDX	TNB	TNT
100% Soil 15	A	6.31	33.9	0.452	30.5
100% Soil 15	B	6.26	33.4	0.446	30.0
100% Soil 15	C	6.36	34.1	0.451	30.5
75% Soil 15/25% Soil 31	A	5.82	32.4	0.247	22.5
75% Soil 15/25% Soil 31	B	5.80	32.3	0.245	22.5
75% Soil 15/25% Soil 31	C	5.81	32.4	0.246	22.5
50% Soil 15/50% Soil 31	A	4.59	30.6	0.224	24.6
50% Soil 15/50% Soil 31	B	4.60	30.6	0.224	24.6
50% Soil 15/50% Soil 31	C	4.70	31.1	0.220	24.9

Table E5
Results for Metals for TCLP for Treated Phase III Soil

Soil Mixture	Carbon Ratio	Replicate	Cadmium, mg/ℓ	Lead, mg/ℓ
100% Soil 15	0.01	A	<0.01	0.063
100% Soil 15	0.01	B	<0.01	<0.05
100% Soil 15	0.05	A	<0.01	<0.05
100% Soil 15	0.05	B	<0.01	<0.05
100% Soil 15	0.10	A	<0.01	<0.05
100% Soil 15	0.10	B	<0.01	<0.05
75% Soil 15/25% Soil 31	0.01	A	<0.01	<0.05
75% Soil 15/25% Soil 31	0.01	B	<0.01	<0.05
75% Soil 15/25% Soil 31	0.05	A	<0.01	<0.05
75% Soil 15/25% Soil 31	0.05	B	<0.01	<0.05
75% Soil 15/25% Soil 31	0.10	A	<0.01	<0.05
75% Soil 15/25% Soil 31	0.10	B	<0.01	<0.05
50% Soil 15/50% Soil 31	0.01	A	<0.01	<0.05
50% Soil 15/50% Soil 31	0.01	B	<0.01	<0.05
50% Soil 15/50% Soil 31	0.05	A	<0.01	<0.05
50% Soil 15/50% Soil 31	0.05	B	<0.01	<0.05
50% Soil 15/50% Soil 31	0.10	A	<0.01	<0.05
50% Soil 15/50% Soil 31	0.10	B	<0.01	<0.05

Table E6
Results for Explosives for TCLP for Phase III Treated Soil 15

Soil Mixture	Carbon Ratio	Replicate	mg/ℓ HMX	RDX	TNB	TNT
100% Soil 15	0.01	A	<0.02	<0.02	<0.02	<0.02
100% Soil 15	0.01	B	<0.02	<0.02	<0.02	<0.02
100% Soil 15	0.05	A	<0.02	<0.02	<0.02	<0.02
100% Soil 15	0.05	B	<0.02	<0.02	<0.02	<0.02
100% Soil 15	0.10	A	<0.02	<0.02	<0.02	<0.02
100% Soil 15	0.10	B	<0.02	<0.02	<0.02	<0.02
75% Soil 15/25% Soil 31	0.01	A	2.96	17.2	0.113	1.95
75% Soil 15/25% Soil 31	0.01	B	3.28	19.0	0.157	5.15
75% Soil 15/25% Soil 31	0.05	A	<0.02	0.219	<0.02	<0.02
75% Soil 15/25% Soil 31	0.05	B	<0.02	0.216	<0.02	<0.02
75% Soil 15/25% Soil 31	0.10	A	<0.02	0.025	<0.02	<0.02
75% Soil 15/25% Soil 31	0.10	B	<0.02	0.020	<0.02	<0.02
50% Soil 15/50% Soil 31	0.01	A	0.366	2.26	<0.02	<0.02
50% Soil 15/50% Soil 31	0.01	B	0.312	1.15	<0.02	<0.02
50% Soil 15/50% Soil 31	0.05	A	<0.02	0.022	<0.02	<0.02
50% Soil 15/50% Soil 31	0.05	B	<0.02	0.012	<0.02	<0.02
50% Soil 15/50% Soil 31	0.10	A	0.081	4.50	<0.02	<0.02
50% Soil 15/50% Soil 31	0.10	B	<0.02	0.020	<0.02	<0.02

Table E7
Results of Bulk Chemistry for RDX and TNT for Additional Soil 15/31 Mixtures for Phase III Study Using 10-Min Carbon Mixing Time

Soil Mixture	Replicate	RDX, mg/kg	TNT, mg/kg
100% Soil 15	A	1,190	1,490
100% Soil 15	B	7,620	6,790
75% Soil 15/25% Soil 31	A	2,390	3,000
75% Soil 15/25% Soil 31	B	2,510	3,020
50% Soil 15/50% Soil 31	A	1,790	2,210
50% Soil 15/50% Soil 31	B	1,790	2,500
12% Soil 15/88% Soil 31	A	202	212
12% Soil 15/88% Soil 31	B	231	279

Table E8
Results for RDX and TNT for TCLP Performed on Additional Phase III Soils Using 10-Min Carbon Mixing Time

Soil Mixture	Carbon Ratio	Replicate	RDX, mg/ℓ	TNT, mg/ℓ
100% Soil 15	0.10	A	0.349	<0.02
	0.10	B	0.356	<0.02
	0.10	C	0.349	<0.02
	0.15	A	0.062	<0.02
	0.15	B	0.053	<0.02
	0.15	C	0.055	<0.02
	0.20	A	0.019	<0.02
	0.20	B	0.015	<0.02
	0.20	C	0.016	<0.02
	0.25	A	0.019	<0.02
	0.25	B	0.008	<0.02
	0.25	C	0.012	<0.02
75% Soil 15/25% Soil 31	0.10	A	0.043	<0.02
	0.10	B	0.041	<0.02
	0.10	C	0.042	<0.02
	0.15	A	0.011	<0.02
	0.15	B	0.014	<0.02
	0.15	C	0.018	<0.02
	0.20	A	0.006	<0.02
	0.20	B	0.012	<0.02
	0.20	C	0.005	<0.02
	0.25	A	<0.02	<0.02
	0.25	B	<0.02	<0.02
	0.25	C	<0.02	<0.02
50% Soil 15/50% Soil 31	0.10	A	0.011	<0.02
	0.10	B	0.008	<0.02
	0.10	C	<0.02	<0.02
	0.15	A	<0.02	<0.02
	0.15	B	<0.02	<0.02
	0.15	C	<0.02	<0.02

(Continued)

Table E8 (Concluded)

Soil Mixture	Carbon Ratio	Replicate	RDX, mg/ℓ	TNT, mg/ℓ
50% Soil 15/50% Soil 31 (Continued)	0.20	A	<0.02	<0.02
	0.20	B	<0.02	<0.02
	0.20	C	<0.02	<0.02
	0.25	A	<0.02	<0.02
	0.25	B	<0.02	<0.02
	0.25	C	0.003	<0.02
12% Soil 15/88% Soil 31	0.10	A	<0.02	<0.02
	0.10	B	<0.02	<0.02
	0.10	C	<0.02	<0.02
	0.15	A	<0.02	<0.02
	0.15	B	<0.02	<0.02
	0.15	C	<0.02	<0.02
	0.20	A	<0.02	<0.02
	0.20	B	<0.02	<0.02
	0.20	C	<0.02	<0.02
	0.25	A	<0.02	<0.02
	0.25	B	<0.02	<0.02
	0.25	C	0.004	<0.02

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13. ABSTRACT *(Maximum 200 words)*

The U.S. Army Umatilla Depot Activity (UMDA) is a 19,700-acre (7,975.70-ha) military reservation that was established as an ordnance depot in 1941. The primary mission of the UMDA is to store, preserve, and perform minor maintenance on conventional and chemical munitions. The UMDA also stores strategic materials for the Defense Logistics Agency and reserve equipment withdrawn from normal service.

Two sites were selected at the UMDA to determine if solidification/stabilization (S/S) could be used for the cleanup of these sites. The two sites are identified as Operable Unit 5 (OU-5) and the Ammunition Demolition Area (ADA) (OU-4). Five soils were chosen for evaluation using current S/S technology. The five sites were identified as Sites 22 and 36 from the OU-5 and Sites 15, 19, and 31 from the ADA. The soils from Sites 22 and 36 were contaminated with heavy metals, and Sites 15, 19, and 31 were contaminated with heavy metals and explosive compounds.

All soils were subjected to physical and contaminant leach tests prior to S/S being applied to the soils. This information gives basic engineering properties of the soils and background data for comparison of the treated soils. Chemical data of the soils indicated that Soils 15 and 19 had the highest concentration of metals and explosive compounds found in the soils

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14. SUBJECT TERMS

Explosive compounds	Solidification/stabilization
Heavy metals	TCLP (toxicity characteristic leaching procedure)
RDX	TNT

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evaluated. Soils 22 and 36 had elevated concentration of heavy metals, while Soil 31 was the least contaminated, indicating low levels of heavy metals and no explosives.

Initial screening tests were performed on the soils to determine the optimal soil/water ratio and to narrow the binder/soil ratio. Portland cement Type I and Portland cement Type I/Class F fly ash were the two binders used to solidify the soils for this study. Based on the results of the physical tests and toxicity characteristic leaching procedure (TCLP) for initial screening tests, binder ratios of 0.1, 0.3, 0.5, and 0.7 cement with a water ratio of 0.2 and cement/fly ash ratios of 0.1/0.1, 0.1/0.3, 0.3/0.1; and 0.3/0.3 with a water ratio of 0.2 were selected for the detailed evaluation portion of this study.

The samples prepared for the detailed evaluation portion of the study were subjected to eight physical tests to determine the physical properties of the various samples. The TCLP was performed on the samples to determine the leaching potential of the various contaminants found in the soils. The soils from OU-5 (Soils 22 and 36) were mixed together to form one soil for the testing since both soils contained only heavy metal contamination. The results of the TCLP show that S/S can be applied to the Soils 22 and 36 soil mixture and to soil from Site 31 to achieve the performance criteria for the cleanup of this site. The results of the TCLP for Soils 15 and 19 show that explosive compounds and some heavy metals leach from the solidified soils and do not meet the performance criteria for the study.

Phase II of the study involved mixing Soils 15 and 19 with Soil 31 to reduce the concentration of explosive compounds in the soils. These soil mixtures were then solidified using the 0.3 cement/0.1 fly ash binder. The results of the TCLP show that these samples failed to meet performance criteria for the study due to explosives and heavy metals leaching from the solidified samples.

Phase III of the study consisted of using the soil mixtures for the Phase II portion of the study and solidifying the soils using a carbon additive. A mixture of Soils 15 and 31 was the only soil evaluated for the Phase III portion of the study. Activated carbon was added to the soil/water slurry and mixed for 10 min before adding the 0.3 cement/0.1 fly ash binder. The results of the TCLP for these samples show that by using activated carbon in the S/S process, the performance criteria for the TCLP can be achieved for both heavy metals and explosive compounds.